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Texas Utilities Company
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I. SUMMARY

On August 2, 1993, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from three employees at the Texas Utilities Electric Company (TU) Martin Lake Steam Electric Station (MLSES) in Tatum, Texas. The requesters reported neurological symptoms such as memory loss, feeling like they were going to "black out," dizziness, and fatigue, particularly among mechanics at the plant. NIOSH investigators conducted a site visit at the facility on November 10, 1993, and May 4-6, 1994.

The NIOSH investigators measured electromagnetic fields (EMF), and collected bulk samples of the fly ash, bottom ash, and lignite. EMF levels were all below the occupational standard of 10 Gauss, with the highest levels of 5 Gauss centered in areas not frequented by the mechanics. Barium, calcium, iron, magnesium, manganese, and titanium were major constituents of the bottom ash, fly ash, and lignite. Employee interviews revealed the current use of a fire resistant hydraulic fluid, Fyrquel EH®, that contained organophosphate compounds, which can affect the central nervous system. Workers reported that this chemical was used without the personal protective equipment (PPE) recommended by the manufacturer.

NIOSH medical investigators: (1) collected blood samples to measure plasma and red blood cell cholinesterase levels among workers either recently exposed to Fyrquel EH®, or presently symptomatic; (2) administered a questionnaire addressing work practices, current symptoms, and a history of symptoms suggestive of acute organophosphate toxicity; and (3) conducted a basic neurological examination. All cholinesterase levels were within the normal range, indicating no recent excessive exposure to cholinesterase-inhibiting compounds. A statistically significant association was found between recall of past symptoms suggestive of acute organophosphate exposure after working with Fyrquel EH® and reported current symptoms. However, the neurological examination revealed no relevant neurologic abnormalities. Inferences from this association are limited because it is based upon recall, and not on an objective measure of previous exposure or cholinesterase activity.

A potential health hazard exists from the use of Fyrquel EH® not in accordance with the manufacturer's safety recommendations. The cause of the presently reported neurologic symptoms was not determined, but employee recall suggests that previous over-exposure to organophosphates with subsequent neurologic effects is a possible explanation among some workers. Recommendations are made in Section IX for safe handling of this class of compounds.

SIC 4911 (power, electric: generation, transmission or distribution): cholinesterase inhibition, hydraulic fluid, neurologic symptoms, organophosphates.

II. INTRODUCTION

On August 2, 1993, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from employees of Texas Utilities Electric Company, Martin Lake Steam Electric Station (MLSES) in Tatum, Texas. Mechanics at this large (2.25 Gigawatt), lignite-fueled electric power plant reportedly had a high prevalence of neurological symptoms (memory loss, feeling like the employee was going to "black out," dizziness, and fatigue). The cause of these symptoms was not able to be determined by the employees' personal physicians. On November 10, 1993, NIOSH investigators conducted an initial site visit to the facility, where the unprotected use of an organophosphate-containing hydraulic fluid, Fyrquel EH®, was discovered. An interim report of this visit was sent in February 1994. Based on this information, NIOSH investigators returned on May 4-6, 1994, to assess worker exposure to this product and to study whether past or present health effects might be related to that exposure.

III. BACKGROUND

A. Work Areas

The MLSES consists of three distinct units, each with its own boiler, generator, stack, and pollution control equipment. The plant employs approximately 200 maintenance workers including 30 supervisors, 30 electricians, and 140 mechanics. The mechanics were divided by the company into three groups, designated “Areas” A (40 workers), B (40 workers), and C (60 workers). These groups were based on job duty and not worksite location within the plant. Area A workers were responsible for the turbines, bottom and fly ash systems and pump room, Area B workers for the bowl mill (machines that grind the lignite), and Area C workers for the scrubbers and lignite handling areas.

B. Union Health Survey

The International Brotherhood of Electrical Workers (IBEW) had conducted a survey of mechanics in the fall of 1993, to determine the extent and severity of the health problem at the MLSES. Twenty-two workers reported health problems to the union during this survey. Fourteen of the employees who completed the survey were from Area A, five were from Area B, one was from Area C, and two were from other locations (warehouse, operations) in the plant. No electricians reported symptoms to the union. Seventeen workers reported dizziness/
lightheadedness, nine reported concentration problems, six reported fatigue or "low energy," and two reported blood pressure changes.

C. NIOSH Medical Interviews

NIOSH medical investigators interviewed 12 workers during the site visit of November 10, 1993. Ten were symptomatic employees, selected by the union because of the severity of their symptoms. Two additional workers were referred by management because they were not on the union list of symptomatic employees. Symptoms reported by interviewed employees included: dizziness or lightheadedness, headaches, feeling like they were going to “black out,” fluctuating blood pressure, fatigue, and inner ear problems (vertigo).

D. Fyrquel EH®

During the course of the medical interviews conducted on November 10, 1993, one worker informed NIOSH investigators about the use of a fire resistant hydraulic fluid Fyrquel EH®. Fyrquel EH® was used in the lines that control the generators to prevent self-ignition of the fluid due to the high pressure needed in these hydraulic lines. This worker believed that it was causing him to have a neurological problem and asked us to determine its composition. Four other symptomatic employees were asked to return to the interview to determine if they had been exposed to this compound during the course of their work; all replied that they had.

The MSDS for Fyrquel EH® on file at the company was not current and no specific determination could be made about the exact composition of Fyrquel EH® at that time. A review of the current MSDS, obtained from the manufacturer of Fyrquel EH®, revealed that this product was composed of 50% trixylenyl phosphate and 50% mixed (unspecified) triaryl phosphate esters. These compounds are cholinesterase inhibitors and capable of causing neurologic effects; trixylenyl phosphate is an inhibitor of both plasma cholinesterase and brain neurotoxic esterase. Other than Fyrquel EH®, no known neurotoxic chemicals were mentioned by interviewed workers or discovered by NIOSH investigators.

E. Review of Past Industrial Hygiene Studies at the MLSES Facility

The TU Electric management provided the NIOSH investigators with copies of the reports from several industrial hygiene surveys that had been conducted at the MLSES facility. From June 1991, through October 1992, 11 industrial hygiene studies were conducted at the MLSES facility by an industrial hygiene consulting firm retained by TU Electric. Approximately 320 time-weighted average (TWA) exposure profiles were developed from personal breathing zone (PBZ) air sampling of fuel and ash operators, equipment operators, foremen, plant mechanics, chemical technicians, electricians, and a storekeeper. In addition, about 175 area air samples were collected from the coal conveying operation, near the Nuva Feeders, welding and cutting operations, the shuttle bus, and near the fly ash silos. The purpose of these studies was to estimate workers' exposures to substances found in coal/lignite dust, fly ash, bottom ash, limestone dust, abrasive blasting dust, welding and cutting fumes, fly ash/scrubber sludge dust, and general yard dust. Air samples were analyzed for respirable dust (269 samples collected), total dust (149), respirable silica (52), total fumes/metal fumes (14), and arsenic (11). The majority of these exposures were below the Occupational Safety and Health Administration’s (OSHA) Permissible Exposure Limits

(PELs) for the above substances.[3] A few PBZ measurements indicated worker overexposure (based on the OSHA PEL). Overexposures to welding fumes occurred during arc gouging and welding of bowl mill doors; overexposure to coal dust occurred during bowl mill maintenance.

A laboratory report dated March 26, 1993, contains the data and results from a metals analysis, made by the industrial hygiene contractor, of nine bulk samples (mostly fly and bottom ash) collected at the MLSES facility. These bulk samples were collected from the hoppers of dewatering bins A (units 1 and 2), B (two samples), C, and D; the weir of dewatering bin A; the low pressure ash water pump; and the recirculation line of an ash water pump. The analysis of these bulk samples revealed that these materials were composed of iron, calcium, and silicon-based materials; one bulk sample did contain residual amounts of sulfur and chlorine. In addition, trace levels of lead and arsenic were found in the bulk samples.

In response to worker health issues identical to those in this HHE, the consultant for TU Electric conducted in-depth exposure assessments on May 20-28, 1993, and August 3-9, 1993 (report dated October 25, 1993). The purpose of this industrial hygiene study was to determine mechanics' exposures to welding-related emissions and volatile organic compounds during the maintenance and repair of the dewatering bins, and during routine operations. All of these sample results were below the relevant OSHA PELs for the chemical compounds evaluated in this study. Several area air samples and a laboratory experiment (cutting a scale which had accumulated in the dewatering bin), however, had elevated concentrations of hydrogen sulfide and sulfur dioxide that would have exceeded their OSHA PELs had they been from a PBZ sample.

IV. EVALUATION CRITERIA

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 thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs)[1]; (2) the American Conference of Governmental Industrial

Hygienists' (ACGIH) Threshold Limit Values (TLVs)[2]; and (3) the U.S. Department of Labor OSHA PELs[3]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and the OSHA PELs included in this report reflect the 1971 values. 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 short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

A. Welding Fume

The composition of welding fumes will vary considerably depending on the alloy being welded, the process, and the electrodes used.[4] Many welding processes also produce other hazards, including toxic gases such as ozone or nitrogen oxides, and physical hazards such as intense ultraviolet radiation. Of particular concern are welding processes involving stainless steel, cadmium or lead coated steel, and metals such as nickel, chrome, zinc, and copper. Fumes from these metals are considerably more toxic than those encountered when welding iron or mild steel. Epidemiological studies and case reports of workers exposed to welding emissions have shown an excessive incidence of acute and chronic respiratory diseases.[4] These illnesses include metal fume fever, pneumonitis, and pulmonary edema. The major concern, however, is the excessive incidence of lung cancer among welders. Epidemiological evidence indicates that welders generally have a 40% increase in relative risk of developing lung cancer as a result of their work.[4] Because of the variable composition of welding emissions, and epidemiological evidence showing an increased risk of lung cancer, NIOSH recommends that exposures to all chemical and physical agents associated with welding or brazing be controlled to the lowest feasible concentration. Exposure limits for each chemical or physical agent should be considered upper boundaries of exposure. The ACGIH TLV for total welding fume, which applies only to manual metal-arc or oxy-acetylene welding of iron, mild steel or aluminum, is 5 mg/m^3 as an 8-hour time-weighted average.[5] The OSHA PEL for total welding fume (as Particulates Not Otherwise Regulated [PNOR]) is 15 mg/m^3.[3]

B. Sub-radiofrequency Electric and Magnetic Fields

The ACGIH has published TLVs for sub-radio frequency electric and magnetic fields (30 kiloHertz [kHz] and below).[5] The TLV for magnetic fields (B) states "routine occupational exposure should not exceed the ceiling value:

$$B_{TLV} \text{ in milliTeslas (mT)} = 60/f$$

where f is the frequency in Hertz." Conversely, the electric field (E) TLV states "occupational exposures should not exceed a field strength of 25 kiloVolts per meter (kV/m) from 0 to 100 Hertz (Hz). For frequencies in the range of 100 Hz to 4 kHz, the TLV ceiling value is given by:

$$E_{TLV} \text{ in Volts per meter (V/m)} = (2.5 \times 10^{6})/f$$

where f is the frequency in Hz. A value of 625 V/m is the exposure limit for frequencies from 4 kHz to 30 kHz."

This means, for example, that at 60 Hz, which is classified as ELF (extremely low frequency), the electric field intensity TLV is 25,000 V/m and the magnetic flux density TLV is 1 mT (or 10,000 mG).

The basis of the ELF E-field TLV is to minimize occupational hazards arising from spark discharge and contact current situations. The B-field TLV addresses induction of magnetophosphenes in the visual system and production of electric currents in the body.

C. Organophosphate Toxicity

Organophosphates typically cause acute illness in humans by binding to and inhibiting acetylcholinesterases (A-ChE) at nerve endings. A-ChE is an enzyme that metabolizes, and thus controls, the amount of acetylcholine (nerve impulse transmitter) available for transmitting nerve impulses. Inhibition of A-ChE causes acetylcholine to accumulate at nerve endings, resulting in increased and continued acetylcholine stimulation at those sites. Symptoms of acute A-ChE inhibition include the following:

increased sweating	chest pain	muscle weakness
blurred vision	breathing difficulty	muscle twitches
increased tears	wheezing	memory problems
increased saliva	nausea and vomiting	decreased concentration
increased nasal & lung secretions	abdominal cramps	diarrhea

Inhibition of ChE activity can be measured either in red blood cells (RBC-ChE) or in plasma (P-ChE). P-ChE activity, though a more sensitive indicator of organophosphate exposure, returns to pre-exposure levels more rapidly than RBC-ChE activity. Therefore, P-ChE values may not reflect the severity of toxicity unless blood specimens are obtained soon after exposure. NIOSH defines an unacceptable exposure to organophosphate as a decrease in RBC-ChE activity to below 70% of the pre-exposure levels.[6]

Some organophosphate compounds have been known to cause an effect known as organophosphate-induced delayed neuropathy (OPIDN). It occurs 8-14 days after exposure and results in a peripheral neuropathy characterized by numbness, tingling, fatigue, or cramps in the calf muscles leading to muscular weakness and paralysis. OPIDN is associated with inhibition of a central nervous system enzyme called neurotoxic esterase (NTE) and not cholinesterase. It has most commonly been associated with triortho-cresyl phosphate (TOCP) and has been the cause of outbreaks of paralysis in the United States, Morocco, and Switzerland.[7] OPIDN has also been associated with other organophosphates besides TOCP including sarin, isofenphos, and leptophos. According to the manufacturer, Fyrquel EH® will inhibit neurotoxic esterase in animals at high doses.

V. METHODS

A. EMF Measurements

Because of the potential for exposure to high EMF at power plants, measurements were made of ELF fields (60 Hz), as that is the frequency of the generated current. The evaluation to determine ELF levels of electric and magnetic fields was designed to survey potential worker exposures to these fields during work tasks, although EMF exposure is not known to be related to neurological problems. The limited number of measurements taken in and around the various facilities were not intended to represent an in-depth evaluation of all ELF EMF present at the site, but were rather intended to identify areas of high exposure (walk-around mode) to determine if they were in areas where workers might frequent during the course of their workday.

Selected magnetic field measurements were made with the EMDEX II exposure monitoring system, developed by Enertech Consultants, under project sponsorship of the Electric Power Research Institute, Incorporated. The EMDEX II is a programmable data-acquisition meter which measures the orthogonal vector components of the magnetic field through its internal sensors. Measurements can be made in the instantaneous read or storage mode. The system was designed to measure, record, and analyze power frequency magnetic fields in units of mG (milliGauss) in the frequency region from 40 to 800 Hz. Measurements were made with this meter in the walk-around mode.

Electric field measurements were made with the Holaday Industries, Incorporated model HI-3602 ELF sensor, connected to a HI-3600 survey meter, which was used to document both the magnitude of ELF electric field and the electrical frequency (as well as the waveforms) produced by such fields. The electric field strength was measured in units of Volts per meter (V/m).

B. Industrial Hygiene

The NIOSH industrial hygienist conducted the following during the site visit of November 1993:

1. A detailed walk-through survey of the MLSES facility. The purpose of the walk-through survey was to observe the variety of tasks performed by the A, B, and C Area mechanics, and to familiarize the NIOSH investigators with the power generation and lignite combustion process.

2. A review of the hazardous communication and personal protective equipment programs.

3. Bulk sampling of the fly ash, bottom ash, and lignite. The reason for collecting bulk samples was to determine if these materials contained any volatile organic compounds, polynuclear aromatic hydrocarbons (PAHs), and metals.

   The bulk samples that were submitted for metal analysis were prepared and analyzed according to methods developed by the Environmental Protection Agency (EPA). Basically, the sample preparation consisted of several digestion steps using nitric, hydrofluoric, and hydrochloric acids; the hydrofluoric acid was neutralized using a boric acid solution. Analysis was performed using an inductively-coupled plasma atomic emission spectrometer. A description of this method was previously supplied by the NIOSH industrial hygienist to TU Electric in a letter dated March 15, 1994.

   NIOSH Method 5506 was used to determine the presence of specific PAHs in the bulk samples.[8] The samples were prepared for analysis by mixing 10 grams (g) of the bulk material with 10 g of sodium sulfate, and extracting with methylene chloride in a Soxhlet extraction apparatus. The extraction was concentrated to 1 milliliter (ml), and the solvent exchanged to acetonitrile. The samples were analyzed by high performance liquid chromatography (HPLC) with both ultraviolet (wavelength of 254 nanometers for absorbance) and fluorescence (wavelengths of 274 nanometers for excitation and 370 nanometers cutoff for fluorescence) detectors.

   A thermal headspace analysis was conducted to qualitatively determine which volatile organic compounds were contained in the bulk samples. Glass sample tubes were filled with 10 to 30 milligrams (mg) of the bulk material, heated to 50 and 200°C in a thermal desorber unit, and injected into a gas chromatograph mated with a mass spectrometer. The mass spectrometer was operated in a full scan mode.

C. Medical Evaluation Methods

1. Study participation

   Participants were selected from the 88 mechanics present on the day of the evaluation using three different criteria.

   a) Group 1 consisted of the symptomatic employees identified by the union. Twenty-two workers had reported neurologic symptoms of unknown etiology in the survey conducted by their union. Fourteen were present on the day of the NIOSH evaluation and participated in the study. Ten worked in Area A and four worked in Area B.

   b) Group 2 consisted of employees who were identified by company records as having worked with Fyrquel EH® or Fyrquel EH® lines as part of their job, either during the preceding 4 months or during the last plant outage in November 1993. Of the 12 workers who were known to have used Fyrquel EH® since November 1993, 10 participated in the study. Nine presently worked in Area A, and one worked in Area C.

c) Group 3 consisted of 30 workers who were not known to be symptomatic or to have worked with Fyrquel EH® in the last 4 months or during the last plant outage and included the remaining 10 Area A workers and a convenient sample of 20 workers selected by the NIOSH medical investigator, in cooperation with the union and management, from the roster of all mechanics at work on the day of the evaluation.

2. Evaluation components

a) Blood testing. All participating workers from Groups 1 and 2 received a blood test for serum and plasma cholinesterase. Fourteen additional workers from Group 3 were selected for blood testing and included the 10 remaining Area A workers and 4 mechanics, selected randomly, from other areas.

Ten mls of blood were drawn from each participant in a tube containing EDTA (ethylene diamine tetra acetic acid). Since cholinesterase may be found in both red blood cells (true cholinesterase) and plasma (pseudocholinesterase), the plasma and cells were separated by centrifugation. The plasma and cells were sent in ice-cooled containers by overnight delivery to a commercial laboratory for analysis of cholinesterase levels with an automated kinetic assay that is based on the colorometric procedure described by Lewis et al.[9]

b) Questionnaire. All participants were asked to complete a self-administered questionnaire that asked about current symptoms, work practices, and the use of personal protective equipment. Workers were also asked if, after working with Fyrquel EH®, they ever experienced symptoms suggestive of acute cholinesterase inhibition such as increased tearing of the eye, increased salivation, blurring of vision, nausea, urinating more often than usual, diarrhea, and headache. Three opposite symptoms (constipation, dry eye, and difficulty urinating) were also asked to distinguish participants with symptoms actually consistent with organophosphate exposure from those with symptoms inconsistent with this condition. Workers who reported at least two of the symptoms suggestive of organophosphate exposure after working with Fyrquel EH®, and none of the opposite symptoms, were considered to have been possibly exposed by Fyrquel EH® in the past.

For the purpose of determining current symptoms prevalence and identifying cases of potential past organophosphate toxicity, the lack of an answer to a symptoms question was considered a negative response. Because of the small number of people in some of the groups, Fisher's exact tests were performed on questionnaire data comparing symptoms prevalence between workers grouped on the basis of exposure, and t-tests were used to compare cholinesterase levels of workers reporting and not reporting symptoms. Fisher's exact tests were also used to compare current symptoms prevalence in workers reporting two or more symptoms suggestive of previous acute organophosphate exposure with those not reporting previous symptoms suggestive of acute toxicity. Analysis was done using SAS® Version 6.08. A p value of <0.05 was considered to be statistically significant.

c) A basic neurological exam. The exam was administered to 35 of the 38 employees undergoing the blood cholinesterase screening (three workers left before the exam was administered). The exam focused on cranial nerves, peripheral sensation, muscle function, coordination, and reflexes to determine if there were any neurological signs that might suggest OPIDN. To minimize observer bias, the examining physician was unaware of the employee's work area or whether the worker was symptomatic. The contents of the exam are contained in the Appendix.

VI. RESULTS

A. EMF Exposure

The intensity of ELF electromagnetic fields (predominantly power line frequencies) were surveyed using a "walk-around" mode. Field intensity levels were usually between 5 and 30 mG, although higher field strengths were found at electric motors and the generator output wires. The output wires are located on the opposite side of the plant from where the mechanics usually work, with the highest measured level being 4.5 Gauss (1 Gauss = 1000 milliGauss). The mechanics are unlikely to be in any of these areas for extended periods of time. Electric fields (between 3 and 4 kV/m) were found underneath the wires carrying the plant output to the transmission lines. An automobile was observed parked underneath those wires and both NIOSH investigators and TU management representatives agreed that parking cars underneath the output power lines should be discontinued. No exposure assessments for individual employees were undertaken for either electric or magnetic fields.

B. Industrial Hygiene

1. Walk-through tour

The mechanics' activities usually center on preventative maintenance; the major exposures are to hydraulic fluids, cleaning solvents, metal fumes emitted from welding mild steel, and re-building or repairing parts/machinery. Leaks of boiler cooling water were evident during the walk-through tour of the plant. These leaks were, in some cases, in the form of a spray that landed on walkways and, in some instances, workers. Since fly ash debris was scattered throughout the plant, the addition of water to this ash created a potential for slips and falls on walkways or stairways throughout the facility.

The boiler cooling water is collected and sent to a holding pond until it is re-used in the facility. The potential for microbiological growth exists in the re-used water since no biocide is added to the water. The possibility for either inhalation or ingestion of this water exists if a worker found him or herself in the spray. However, it is unlikely that exposure to microbiologicals in the cooling water would result in the symptoms reported at the MLSES and NIOSH investigators did not analyze this water.

2. Hazard communication and personal protective equipment

There was extensive use of various chemicals at the facility and the company maintained a computerized data base of material safety data sheets (MSDSs) of approximately 10,000 chemicals, of which the MLSES facility used about 400. It was provided by TU Electric headquarters and apparently contained many more compounds than were used in the plant. Since it came from a centralized location, updating MSDS sheets for an individual plant or a particular chemical appeared to be difficult. For example, the Fyrquel EH® MSDS was outdated and no longer reflected the current formula for the compound.

MLSES did have a PPE program, with the PPE being centrally located in and distributed from the shop area. The NIOSH investigators observed there was no consistent use of PPE, and the decision as to whether to use PPE was left to the discretion of the worker. During interviews with workers, workers appeared confused regarding the type of glove to be used for a given job. NIOSH investigators asked for a sample of gloves from the central supply area for particular chemical usage. Central supply personnel obtained gloves that were available to employees at MLSES, but neither employees nor management at the closing meeting could determine which glove would be used for a particular task.

3. Results from the analysis of the NIOSH bulk samples

The results from the analysis of the bulk materials for metals are presented in Table 1. The bottom ash, fly ash, and lignite are similar in that barium, calcium, iron, magnesium, manganese, and titanium are major constituents of these materials. Conversely, the bottom ash and fly ash contain higher amounts of aluminum, whereas a lower level of aluminum was found in the lignite. The following metals were not detected in the bulk samples: arsenic, cadmium, molybdenum, lead, platinum, selenium, silver, sodium, tellurium, and thallium.

An interpretation of the PAH data (Table 2) is difficult due to the nature of the bulk materials. The bottom ash, fly ash, and lignite are heterogeneous in composition; i.e., they consist of many different substances in varying amounts. During the HPLC analysis, other substances in these materials interfered with the quantitation of many of the PAHs. Thus, the reported values (identified in Table 2 by preceding the value with a "less than" [<] symbol) are the potentially maximum level of that PAH in the given bulk sample. Because of the nature of the interferences, it is difficult to determine if the detector's response was related to the PAH, the interfering compound, or a combination of both. The actual PAH level may be considerably lower than the stated amount. In general, the PAH levels seem to be higher in the lignite when compared to the bottom and fly ash. PAHs are flammable at the appropriate temperature, and were probably burned-off during the combustion process within the boilers.

Very few organic compounds were found when the bulk materials were heated to 50 and 200˚C (data not shown). In fact, organic compounds were only detected in the lignite and fly ash samples that were heated to 200˚F. These compounds consisted mostly of small amounts of aliphatic hydrocarbons (pentadecane, tetradecane, and hexadecane) and siloxane compounds.

C. Medical

1. Blood testing for serum and plasma cholinesterase

No worker had either a red blood cell cholinesterase level or a plasma cholinesterase level outside of the reference range. Red blood cell cholinesterase ranged from 9,300 International Units/liter (IU/L) to 13,300 IU/L, with a mean of 11,403 IU/L (reference range 7,700-17,500 IU/L) and plasma cholinesterase ranged from 2,300 IU/L to 4,800 IU/L, mean 3,361 IU/L (reference range 1,400-5,600 IU/L).

Red cell cholinesterase level was not statistically related to reported contact with Fyrquel EH® fluid in the last 4 months or with ever having worked on pumps or lines containing Fyrquel EH® fluid. There was no difference in either mean plasma cholinesterase or mean red cell cholinesterase levels in workers reporting any of the current symptoms when compared to asymptomatic participants.

2. Questionnaire results

The questionnaire was administered to the 54 workers participating in the study. Of the questionnaire participants, 29 workers were from Area A, 12 were from Area B, and 13 were from Area C. The mean age of the questionnaire respondents was 42 years and the mean number of years they had worked at MLSES was 13. All respondents classified themselves as mechanics, 94% reported that they welded on the job, and 100% reported that they cut materials with a torch as part of their job. Current symptoms prevalence among all study participants is given in Table 3.

Forty-six workers (85%) reported ever having come in “contact” with Fyrquel EH®. Seventeen (45%) of the workers participating in the blood testing reported “contact” with Fyrquel EH® over the last 4 months (Table 4). Nine of the 10 (90%) Group 2 workers reported contact with Fyrquel EH® over the last 4 months and four of those reported contact four times or more, which corroborated the employer work records. Only 2 of the 30 (7%) Group 3 workers reported contact with Fyrquel EH® fluid over the last 4 months and that was only one time. Forty-three respondents (80%) reported "ever" having skin contact with Fyrquel EH® fluid and 16 (29%) reported having had skin contact within the last 4 months. Of workers reporting skin contact, the hands were most commonly found to have contact with the Fyrquel EH® fluid (100%), followed by the arms (84%), legs (40%), and face (33%). Forty workers (74%) reported "ever" having the Fyrquel EH® fluid in contact with their clothing. One worker (3%) reported that clothing was always changed if it came in contact with the Fyrquel EH® fluid, 10 workers (26%) reported they sometimes changed their clothing, and 28 (72%) workers reported that they never changed their clothing. Of the 46 workers who ever had contact with Fyrquel EH®, two (4%) reported that they always wore gloves while working with the Fyrquel EH® fluid, 13 (28%) reported that they wore them “sometimes,” and 31 (72%) reported they never wore gloves. Five workers (10% of the 51 answering the question) reported that they always wore a respirator when they welded; 31 (61%) reported wearing one "sometimes," and 15 (30%) reported “never” wearing a respirator when they welded.

Comparing the groups of workers who were not selected on the basis of symptoms (Groups 2 and 3), revealed that those workers who reported recent exposure to Fyrquel EH® based on employer records (Group 2) reported increased symptoms prevalence for all symptoms when compared to workers without known recent exposure (Group 3). The most common symptoms that were reported more than once a month among Group 2 workers were sinus problems (80%), memory problems (40%), difficulty focusing the eye (50%), dizziness (40%), and balance problems (40%) (Table 5). Although there was no statistically significant difference in any individual symptoms prevalences between Groups 2 and 3, the fact that Group 2 had a higher prevalence for all nine studied symptoms is statistically significant (p=0.002). If symptoms that are not known to be related to organophosphate exposure are eliminated (rash and sinus problems), the increased prevalence of all of the remaining current symptoms among Group 2 workers is still statistically significant (p=0.008).

The questionnaire revealed that 22 Group 3 workers had historical exposure to Fyrquel EH®, although none was known to have worked with Fyrquel EH® in the last 4 months. The group was divided by exposure to Fyrquel EH® "ever" or not, and prevalence rates for having “ever” experienced the current symptoms was compared between groups. The group reporting they had "ever" had contact with Fyrquel EH® had higher symptoms prevalence for “ever” having had a current symptom for all symptoms except sinus problems. The differences were not statistically significant, with the exception of weakness, which was statistically significant (Table 6). However, having eight out of nine prevalences higher in an exposed group is statistically significant; the probability of observing eight out of nine symptoms by chance alone would be 0.037. “Sinus problems” was the one symptom that was not higher in the exposed group and one would not expect that to be related to organophosphate exposure.

Three workers, all from Area A, reported four or more symptoms suggestive of acute cholinesterase toxicity after use of Fyrquel EH® fluid, and none of the inconsistent symptoms. Eight additional workers reported two to three symptoms suggestive of acute cholinesterase toxicity (also with none of the inconsistent symptoms) after working with Fyrquel EH® fluid. Six presently performed Area A job duties, one Area B job duties, and one Area C job duties.

Workers who had a history of exposure to Fyrquel EH® fluid and reported having two or more symptoms suggestive of acute organophosphate toxicity after working with it, were more likely to experience all of the current symptoms at least once a week, and were more likely to report feeling like they were going to “black out” at least once a month (Table 7).

D. Neurologic Exam

No significant detectable neurological signs were detected with the exception of bilaterally exaggerated tendon reflexes (biceps or knee) in 14 (40%) of the examined persons and an ulnar neuropathy in one worker. The exaggerated tendon reflexes were not related to recall of previous symptoms suggestive of acute organophosphate toxicity or the employee working in a particular area of the plant.

VII. DISCUSSION

The major exposures to mechanics in Areas A, B, and C are to welding fumes, volatile organic solvents, and hydraulic fluid. Exposure to certain metal fumes (e.g., arsenic, lead, manganese) and volatile organic compounds (VOCs) in high concentrations can produce neurologic symptoms similar to some of those reported by workers at the MLSES facility. Typically, long lasting sequela are not associated with these compounds after a period of no or reduced exposure. However, past industrial hygiene monitoring did not detect any substantial exposure or overexposure to either metal fumes or VOCs.

TU Electric's consultant did find that mechanics may be overexposed to total welding fume (refer to Table 1), particularly when working on the dewatering bins. The NIOSH investigators believe that this occurrence is infrequent and probably does not play a role in producing the reported neurologic symptoms. Nonetheless, TU Electric should provide workers performing welding and cutting with adequate protection from the emissions produced during these operations. The NIOSH policy on welding and cutting exposures provides recommendations for protecting workers performing these tasks.[4]

The handling procedures and safety requirements for the use Fyrquel EH® and other fire resistant hydraulic fluids have been addressed by the United States Navy.[10] The Navy process instructions detail the use of the following:

1. Protective garments to minimize skin contact. These include face shields, coveralls, or goggles.

2. Respiratory protection. Respiratory protection is required when fluid misting is occurring from leaks or when the material is heated to greater than 150°F.

3. Personal hygiene. No smoking, eating, or drinking are allowed when working with hydraulic fluid. Contaminated work clothing should be removed after working with the hydraulic fluid and placed in plastic bags for controlled laundering.

4. On-site washing and decontamination facility. Since skin contact may occur even when protective garments are worn, a facility where the skin can be promptly washed is necessary.[10]

The improper use of organophosphate-containing materials such as Fyrquel EH® may result in the development of classical effects of acute cholinesterase inhibition, including: increased lacrimation, salivation, blurred vision, nausea, headache, miosis, diarrhea, and weakness.[11] Researchers have also noted a wide variety of chronic, non-specific neuropsychological symptoms associated with previous acute cholinesterase inhibition including: difficulty in maintaining appropriate attention and alertness, disturbed memory,[12] decreased visual memory, impaired problem solving, and declining motor steadiness, dexterity,[13] and motor skills.[14] Rosenstock et al., reported a persistent decline in neuropsychological functioning even after only one episode of clinically significant toxicity from organophosphates.[14] They found lowered performance on all neuropsychological tests (auditory attention, visual memory, visuomotor speed, sequencing and problem solving, and motor steadiness) among workers who had been acutely poisoned with organophosphates in the past. Steenland et al., found significantly worse performance on two of ten neurobehavioral tests (mood scales and sustained visual attention test) and reduced vibrotactile sensitivity after previous organophosphate toxicity.[15] Although the workers in these studies did not exhibit symptoms identical to those reported by mechanics at MLSES, a relationship between having been previously exposed to cholinesterase-inhibiting compounds and developing later neurological symptoms is suggested.

Other studies have reported different neurological symptoms associated with past exposure to organophosphates, and some symptoms are similar to those reported by workers at MLSES. Gershon and Shaw, in a study of workers exposed to organophosphorus insecticides, reported mental confusion, weakness, concentration difficulty, and short-term memory defects (particularly slowness of recall).[16] In a review of studies of chronic neurobehavioral effects of organophosphates, the EPA reported that the most commonly reported delayed effects were irritability, short-term memory impairment, inability to concentrate, confusion, and depression. Symptoms reported in two or more reviewed studies included visual disturbances, persistent headaches, muscle aches and pains, fatigue, psychomotor impairment, and nervousness.[17] Workers who manufactured leptophos, an organophosphate insecticide, reported symptoms of confusion, headaches, disorientation, and altered emotional and mental states.[18] A study by Metcalf and Holmes suggested that chronic exposure to organophosphates can produce symptoms such as difficulty in thinking and in maintaining alertness, disturbed short-term memory, persistent muscular aches and pains, and abnormal EEG (electro-encephalogram). These symptoms may be irreversible or slowly reversible.[10]

The MSDS for Fyrquel EH® clearly mentions the possibility of inhibition of both cholinesterase and NTE and reports nerve damage in animals. The MSDS states that signs and symptoms of nerve damage may include “weakness, numbness and a tingling sensation of the hands and feet, muscle cramps and loss of motor function.” However, neurological signs were not evident on the clinical exam administered to workers at MSLES Texas Electric, but 14 employees did exhibit exaggerated tendon jerk reflexes. Exaggerated tendon jerk reflexes are a non-specific finding whose etiology ranges from normal variation to a variety of conditions of the central or peripheral nervous system and these findings were not related to any current symptoms at MLSES.

A major limitation of this study was the reliance on the self reporting of past symptoms to define possible organophosphate toxicity, since past cholinesterase levels were unknown. NIOSH investigators tried to be conservative in the analysis and required the recall of two symptoms consistent with cholinesterase inhibition that occurred after the use of Fyrquel EH®, in order to be included in the "exposed" group, and eliminated workers who reported inconsistent symptoms. Without corroborating environmental or medical data, we cannot be certain that workers had organophosphate exposure. Another limitation was that the original study was designed to evaluate blood and plasma cholinesterase levels in symptomatic workers or workers who were known or more likely to be exposed to Fyrquel EH® in the last 4 months; it was not designed to evaluate past acute organophosphate toxicity. However, the temporal association of reporting symptoms suggestive of cholinesterase inhibition with exposure to a cholinesterase inhibiting compound supports the possibility of organophosphate toxicity.

VIII. CONCLUSIONS

Although the source of the workers' complaints was not definitely determined, the statistical association between past symptoms suggestive of organophosphate over- exposure and current neurologic symptoms suggests the possibility of previous episodic excessive exposure to Fyrquel EH®. However, the use of recall of symptoms as a marker for cholinesterase inhibition is a major limitation of the study. In any case, continued use of this chemical demands strict adherence to manufacturers' recommendations for safe handling, as detailed in the MSDS.

IX. RECOMMENDATIONS

1. MSLES management should improve their OSHA hazardous communication program so that employees are aware of the hazards of the various chemicals that they work with while on the job and the proper personal protective equipment required for each chemical.

2. The MSDS program should include up-to-date MSDSs for chemicals that are used at the workplace. There should be a system of easy employee access to MSDSs that does not require unreasonable familiarity with the computerized system.

3. The personal protective equipment program needs to be improved so employees are aware of what equipment is required for each job. Though the elements of such a program are in place (a cache of various types of gloves and the availability of MSDSs), there is little connection between these elements. Thus, employees may not be aware of which glove is appropriate for a given chemical. It was not clear to the NIOSH investigators that employees or management knew which glove should be worn for a particular task.

4. NIOSH investigators recommend that all welding and cutting operations be equipped with fixed-station, local exhaust ventilation systems that exhaust the air outside of the workplace. In situations where this is not feasible, a movable hood with a flexible duct may be used. The hood design, flow rate, and capture velocity at the point of welding/brazing should be designed to effectively capture and remove contaminants away from the worker.[4]

5. In situations where engineering controls are not technologically feasible, workers shall be provided with and use appropriate respiratory protection. Minimum requirements for a respiratory protection program are set forth in *29 CFR 1910.134*, and must include a written respiratory protection program, regular worker training, airborne exposure monitoring, routine procedures for maintenance, proper storage of respirators, and fit testing of all workers who may need to wear a respirator.[19] TU Electric should conduct routine industrial hygiene surveys of workers performing welding and cutting operations to determine the extent of exposure. Surveys should be performed whenever changes in the work processes or conditions are likely to change worker exposures. Though not all workers have to be

monitored, a sufficient number of samples should be collected to characterize the exposures to all workers potentially exposed. Variations in work habits, production schedules, worker locations, and job functions should be considered when making decisions on sampling locations, times, and frequencies.

6. The water lines that are leaking near employees' work areas should be repaired so that no leaks are present, both to decrease the possibility of slipping and falling and to decrease the possibility of exposure to possibly contaminated water. The lines should be checked for microbiological growth and, if excessive, TU Electric should take measures to control that growth.

7. NIOSH investigators suggest that the safety recommendations given below for safe use of fire-resistant hydraulic fluids, be implemented. These recommendations are not necessarily restricted to the use of Fyrquel EH® and are generalizable to other chemical exposures as well. They include:

   a) Workers should be provided with proper shower and locker facilities for changing into and out of their work clothes. TU Electric should consider providing workers with clean uniforms at the beginning of every workshift, and with the opportunity to change into a clean uniform if the current uniform becomes contaminated or torn. To prevent cross-contamination, work and street clothing should not be stored in the same locker or space. Also, workers should be encouraged to shower before leaving the workplace. Contaminated uniforms or clothing should not be brought home for laundering.

   b) Eating, drinking, and smoking should be prohibited in all work areas, and smoking should be restricted to designated smoking rooms or outside.[20] The break areas for eating and drinking should be cleaned and maintained on a regular basis. Workers should wash their hands before eating or drinking.

   c) Manufacturers' recommendations concerning safe use of all products, including respirators and protective clothing, should be followed. Because of its toxicity, attention should be directed to the safe use of Fyrquel EH® and its special handling requirements. Part X of its MSDS, titled "Industrial Hygiene," states that "During the development of safe handling procedures, consideration should be given to the need for cleaning of equipment and piping systems to render them nonhazardous before maintenance and repair activities are performed." According to the manufacturer's representative, flushing with water is insufficient for decontamination.

8. Improvements should be made in the safety-related signs and postings throughout the plant. Signs should be easy to read and understand, placed in a prominent location, and inspected and maintained on a regular basis.

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Copies of this report have been sent to:

1. Texas Utilities Electric Company
2. Confidential employee requestors
3. Local 2337 IBEW
4. OSHA Region IV

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.

TABLE 1
Results from the Metals Analysis of Bottom Ash, Fly Ash, and Lignite
HETA 93-1062-2558
Texas Utilities, MLSES
Tatum, Texas

Metals	Bottom Ash[1]	Fly Ash[1]	Lignite[1,2]
Aluminum	41000	80000	80
Barium	2200	2400	200
Beryllium	2	4	ND
Calcium	59000	74000	10000
Cobalt	16	24	5
Chromium	50	99	10
Copper	56	120	12
Iron	68000	58000	5000
Lithium	49	61	ND
Magnesium	13000	18000	2000
Manganese	840	890	100
Nickel	41	59	10
Phosphorus	300	200	ND
Titanium	5100	6600	350
Vanadium	100	180	21
Yttrium	34	47	13
Zinc	12	84	16
Zirconium	74	79	ND

1 Results expressed in units of micrograms of metal per gram of bulk material.
2 ND - none detected; metal not detected in bulk material.

TABLE 2
Results from the PAH Analysis of Bottom Ash, Fly Ash, and Lignite

HETA 93-1062-2558
Texas Utilities, MLSES
Tatum, Texas

Specific PAHs	Bottom Ash[1,2,3]	Lignite[1,2]	Fly Ash[1,2]
Naphthalene	ND	<700	<700
Acenaphthylene	<18	<500	<410
Acenaphthene	ND	<15000	<320
Fluorene	<39	<1500	<63
Phenanthrene	10	<470	29
Anthracene	<11	<64	<70
Fluoranthene	2	1800	57
Pyrene	0.4	500	9
Benz(a)anthracene	ND	<560	10
Chrysene	ND	<580	15
Benz(b)fluoranthene	ND	2300	<5
Benz(k)fluoranthene	ND	<640	<3
Benzo(a)pyrene	ND	890	<3
Indeno(1,2,3-cd)pyrene	ND	<1600	<3
Dibenz(a,h)anthracene	ND	420	<6
Benzo(g,h,i)perylene	ND	<620	<5

1 Results expressed in units of micrograms of PAH per kilogram of bulk material.
2 A result preceded by a "<" indicates that other substances interfered with the proper quantitation of the specific PAH; the value is the limit of detection above which nothing was detected.
3 ND - none detected; PAH not detected in bulk material.

TABLE 3
Symptoms of Workers - All study participants
HETA 93-1062-2558
Texas Utilities, MLSES
Tatum, Texas
n=54

Symptom	Percent reporting symptom "ever" at work	Percent reporting symptom more than once a week	What happened to the symptom at times when worker was away from work (e.g., holidays, weekends - percent)		
			gets worse	stays the same	gets better
dizziness	56	17	2	33	17
nausea	28	9	0	13	13
weakness	46	13	0	31	19
sinus problems	89	50	2	50	24
balance problems	44	15	0	28	9
memory problems	48	26	0	26	0
rash	44	11	0	26	11
difficulty with focusing the eye	46	26	0	33	6
feeling like you were going to "black out"	33	6	0	20	9

TABLE 4
Number of times blood test participants were in contact with Fyrquel EH® fluid in the last four months
HETA 93-1062-2558
Texas Utilities, MLSES
Tatum, Texas

Number of times worked with EH fluid in the last four months	Number of workers blood test participants n=38	Percent
0	16	42
1	5	13
2	5	13
3	2	5
4	2	5
6	1	3
8	1	3
10	1	3
missing response	2	5
never used EH fluid	3	8

TABLE 5
Prevalence of Symptoms Occurring at Least Once a Month in Workers By Exposure Status
HETA 93-1062-2558
Texas Utilities, MLSES
Tatum, Texas

Symptom	Group 2 (known recent Fyrquel EH® exposure - percent) n=10	Group 3 (Unknown symptoms and exposure status - percent) n=30	p value (2-tailed Fisher's exact)
dizziness	40	17	0.21
nausea	20	10	0.59
weakness	30	27	0.68
sinus problems	80	57	0.22
balance difficulty	40	17	0.20
memory problems	40	27	0.69
rash	30	17	0.42
difficulty with focusing the eye	50	20	0.12
feeling like you were going to "black out"	20	3	0.16

TABLE 6
Fyrquel EH® Exposure & Symptoms Prevalence ("ever") in Group 3 (no known symptoms or exposure)

HETA 93-1062-2558
Texas Utilities, MLSES
Tatum, Texas

Symptom	Percent reporting symptom "ever" and no history of Fyrquel EH® exposure n=7	Percent reporting symptom "ever" with history of Fyrquel EH® exposure n=22	p value (chi-square)	Number
dizziness	14	45	0.14	29
nausea	14	26	0.52	30
weakness	0	48	0.02	30
sinus problems	85	78	0.67	30
balance problems	0	32	0.09	29
memory problems	14	41	0.20	29
eye focusing problems	29	30	0.92	29
rash	14	50	0.10	29
feeling like you were going to "black out"	0	22	0.18	30

TABLE 7
Present symptoms with history of symptoms suggestive of acute organophosphate toxicity
HETA 93-1062-2558
Texas Utilities, MLSES
Tatum, Texas

Present Symptom	Number reporting symptom at least once a week	Number reporting history of two or more symptoms suggestive of acute organophosphate toxicity and present-day symptom more than once a week	p value (2-tail Fisher's exact test)
dizziness	9	6	0.002
nausea	5	3	0.05
weakness	7	4	0.03
sinus problems	27	10	0.02
problems with balance	8	7	<0.0001
memory problems	14	5	0.1
difficulty in eye focusing	14	5	0.1
rash	6	3	0.1
feeling like you were going to "black out" *	10	7	0.002

* Symptom reported more than once a month instead of at least once a week.

APPENDIX

The clinical neurological examination was aimed at detecting any clinical neurological anomalies in the central or peripheral nervous system. Motor, sensory functions, and coordination were assessed without regard for the exact dermatomal distribution. The examination consisted of:

- a) cranial nerve exam
  - 1) eye movements
    - a) lateral rectus muscle
    - b) medial rectus
    - c) nystagmus
  - 2) facial nerve
  - 3) trigeminal nerve
    - a) ophthalmic n.
    - b) mandibular n.
    - c) maxillary n.

- b) superficial sensation
  - 1) upper body
  - 2) lower body

- c) muscle tone
  - 1) upper body
  - 2) lower body

- d) muscle power
  - 1) upper body
  - 2) lower body

- e) coordination

1) finger-nose
   a) eyes open
   b) eyes closed
2) knee heel

f) reflexes
1) knee
2) biceps

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