HEALTH HAZARD EVALUATION REPORT 72-74-51
HAZARD EVALUATION SERVICES BRANCH
DIVISION OF TECHNICAL SERVICES

Establishment : Western Electric Company, Inc.
Dublin, California

Report Prepared By : Melvin T. Okawa, Industrial Hygienist
Arnold Bodner, M.D., Medical Officer

Field Evaluation : Melvin T. Okawa, Industrial Hygienist
Arnold Bodner, M.D., Medical Officer
Carl Ellison, M.D., Medical Officer
James Jones, Industrial Hygienist
Lucia Eckroth, Research Assistant
Phillip Polakoff, M.D, Medical Officer

Laboratory Analyses: Russell H. Hendricks, Ph.D.
DLCD, Salt Lake City, Utah

Larry K. Lowry, Ph.D., Research Chemist
DLCD, Cincinnati, Ohio

Originating Office : Jerome P. Flesch, Chief
Hazard Evaluation Services Branch

June 1973

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45202

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HEALTH HAZARD EVALUATION REPORT 72-74
WESTERN ELECTRIC COMPANY
DUBLIN, CALIFORNIA

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I. SUMMARY DETERMINATION

A. Introduction

Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6), authorizes the Secretary of Health, Education, and Welfare, following a written request by any employer 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.

The National Institute for Occupational Safety and Health (NIOSH) received such a request from an authorized representative of employees regarding exposure to solvent vapors in the printed wiring board processing area of the Western Electric Company plant, Dublin, California.

B. Federal Standards

Three potentially toxic substances were found in the place of employment, the printed wiring board processing area of the plant. All three agents have established Federal standards which are promulgated by the U.S. Department of Labor (Federal Register, Part II, Vol. 37, No. 202, §1910.93, Table G-1 and G-2).

Substance	Federal Standard
Trichloroethylene	100 ppm*
N-Propyl Acetate	200 ppm
Toluene	200 ppm

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*ppm - parts of vapor per million parts of contaminated air by volume at 25°C and 760 mm of Hg pressure. The standard is based on a time-weighted average for an eight hour per day (40 hour per week) exposure.

C. Environmental Evaluation Results

Environmental investigations were conducted by NIOSH on September 13, 1972; December 7, 1972 and February 16, 1973.

Nine (9) personal breathing zone samples were collected on employees spraying board units with a lacquer containing n-propyl acetate and toluene. The n-propyl acetate (NPA) concentrations ranged from nondetectable (0) to 32 parts per million (ppm) with an average concentrations for NPA and (TOL) respectively were 15.2 and 6.0 ppm. Toluene (TOL) levels were between 0 and 12 ppm with an average of 6.0 ppm. Trichloroethylene (TCE) levels ranged from 13-40 ppm with an average 25.3 ppm.

Twelve personal breathing zone samples were collected on employees washing board units with TCE. The NPA and TOL levels ranged from 0-6 and 0-2 ppm respectively. The TCE concentrations ranged from 6-82 ppm (average 39.0 ppm).

Twelve breathing zone samples were collected on workers in the testing area. The NPA and TOL levels ranged from 0-21 and 0-6 ppm respectively. TCE levels ranged from 8-44 ppm (average 24.4 ppm).

Six samples were collected on mass solder machine operators. Only a trace of NPA was found and TOL was not detected in any of the samples. TCE concentrations ranged from 23-87 ppm with an average of 44.0 ppm. Four samples were taken while mass solder operators cleaned their machines with TCE. TCE levels ranged from 30-106 ppm (average 70.5 ppm). Only one sample out of 43 showed a level of TCE which represented an excursion above the 100 ppm Federal standard which is based on an eight-hour time-weighted average exposure. This level (106 ppm) occurred when NIOSH investigators were monitoring a short-term cleaning operation at the mass solder machine.

D. Medical Evaluation Results

Twenty-four persons were interviewed by NIOSH physicians on December 7, 1972. All but three people had some symptoms which they attributed to their exposures to solvents. The most common symptoms of the 24 workers were: (1) nausea (70.8%), (2) headache (54.2%), (3) dizziness (33.3%), and (4) mucous membrane irritation (25.0%). All the workers felt that their symptoms were relieved completely when they had left the work environment for several hours.

Symptoms have occurred on a fairly regular basis, and were reported frequently at the times of our visits.

Twenty exposed workers and nine control subjects submitted eight-hour urine samples on February 16, 1973 which were analyzed for TCE metabolite (trichloroacetic acid and trichloroethanol) levels. The trichloroacetic acid (TCA) and trichloroethanol (TC-OH) levels are expressed in milligrams per liter (mg/l) or milligrams per gram of creatinine (mg/g). The control samples showed a TCA range of 0-29 mg/l or 24 mg/g and a TC-OH range of 0-27 mg/l or 0-18 mg/g. These levels are slightly higher than those found in control subjects from a previous NIOSH investigation indicating that these people were getting exposure to TCE at the plant. The exposed persons samples showed a TCA range of 17-196 mg/l or 11-145 mg/g and a TC-OH range of 38-121 mg/l or 22-111 mg/g. These levels were preshift values. Post work TCA levels did not vary much, but the TC-OH levels were elevated to a range of 82 - 267 mg/l or 52 -179 mg/g which indicated that these individuals were exposed to TCE during the day. The TC-OH levels in urine correlate well with the amount of TCE in the atmosphere. The urine TC-OH levels indicated that these workers were being exposed to TCE levels in the atmosphere ranging below 50 ppm on a time-weighted average exposure. No safe urine TCE metabolite levels have been developed for an occupationally exposed group of people at this time.

E. Toxicity Determination

Based upon the results of the investigation reported above, it is our determination that the substance trichloroethylene is toxic to workers in the printed wiring board unit operations at the concentrations and conditions used and found at the time of this evaluation.

Trichloroethylene is the only agent present is significant amounts throughout the work area and is thought to be the cause of the toxic manifestations of symptomatology occurring frequently in workers during periods of heavy usage, although environmental levels detected were below the current Federal standard.

The reported condition represents a hazard to the health of workers, although not considered serious since no permanent physical changes occur, and may also present the potential for a safety hazard due to the general reduction in motor function, ability to concentrate and increased likelihood of accidents on such occasions.

It is also judged that the substances, N-propyl acetate and Toluene, are not potentially toxic at the concentration used or found.

F. Distribution

Copies of the Summary Determination of the evaluation are available upon request from the Hazard Evaluation Services Branch, NIOSH, U.S. Post Office Building, Room 508, 5th and Walnut Streets, Cincinnati, Ohio 45202. Copies have been sent to:

a) Western Electric Company, Dublin, California

b) Authorized Representative of Employees

c) U.S. Department of Labor - Region IX

For purposes of informing the approximately twenty-five (25) "affected employees," the employer will promptly "post" the Summary Determination in a prominent place(s) near where affected employees work for a period of 30 calendar days.

II. INTRODUCTION

Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6), authorizes the Secretary of Health, Education, and Welfare, following a written request by any employer 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.

The National Institute for Occupational Safety and Health (NIOSH) received such a request from an authorized representative of employees regarding exposure to solvent vapors from trichloroethylene and n-propyl acetate at the Western Electric Company plant, Dublin, California.

The Western Electric Company is a manufacturer of telephone transmission equipment of all types. Approximately 500 people (400 in production and 100 in administration) work in the plant during two full shifts, and about 20 to 30 persons are employed in the section of the facility described in the health hazard evaluation request.

III. BACKGROUND HAZARD INFORMATION

A. Standards

Three potentially toxic substances were found in the place of employment. All three agents have established Federal standards which are promulgated by the U.S. Department of Labor (Federal Register, Part II, Vol. 37, No. 202, Section 1910.93, Tables G-1 and G-2).

Substance	Federal Standard
Trichloroethylene	100 ppm*
N-Propyl Acetate	200 ppm
Toluene	200 ppm

B. Toxic Effects

There is ample literature on the toxic effects of trichloroethylene (TCE) on man. From studies performed on levels of TCE in blood, it has been observed that arterial levels are much higher than venous levels because TCE, being very fat soluble, is rapidly absorbed from the blood stream.[1]

Trichloroethylene is rapidly absorbed through the lungs, and following absorption, the compound is metabolized to trichloroacetic acid (TCA) and trichloroethanol (TC-OH). Trichloroethanol is the most toxic metabolite

*ppm - parts of vapor per million parts of contaminated air by volume at 25°C and 760 mm of Hg pressure. The standard is based on a time-weighted average for an eight hour per day (40 hour per week) exposure.

of TCE. Both compounds are conjugated with glucuronic acid and excreted from the body in the urine. Other possible metabolites of TCE include urocholalic acid, monochloroacetic acid, and chloroform.

Stewart and his associates exposed human volunteers to 200 parts per million (ppm) of TCE in one study.[2] TCE blood levels reached a maximum reading after 2 hours, fell to 2/3 of this level after 3 hours, and 20 minutes after exposure had terminated, fell to 1/6 of the original maximum concentration. Analysis of expired air samples from the volunteers after a period of 5 hours of no exposure showed that TCE was barely perceptible.

Retention of metabolites has been estimated to account for over 56% of the TCE that is inhaled. Metabolite retention can be broken down into the following: 7 - 27% TCA, 22% TC-OH, 22 - 45% urocholalic acid, and possible trace amounts of monochloroacetic acid and chloroform.

Browning reviewed the histopathological changes of chronic TCE poisoning in animals.[1] The findings included such changes as liver inflammation and cirrhosis, enlarged spleen, glomerular and tubular lesions of the kidney involving capillary dilatation and white blood cell infiltrates, emphysematous and inflammatory effects in the lungs, and hyperemia, edema, and small hemorrhages in the cerebrum and margins of the cerebellum.

Kleinfeld and Tabershaw reported 4 cases of fatal human exposure in one report.[3] No gross anatomical changes were noted during autopsy other than a general visceral congestion. Other reports of fatal TCE poisoning have also been reported, and post mortum findings include pulmonary edema, cardiac dilatation, renal congestion, and vascular congestion of the brain.[1] Browning attributes deaths from TCE exposure to ventricular fibrillation or standstill and to acute pulmonary edema.

In animals, TCE is a narcotic and anesthetic capable of causing complete unconsciousness. Browning reports almost immediate anesthesia in rats breathing 4,800 ppm of TCE and that 3,000 ppm will produce complete anesthesia over a short period of time.[1] The effect of TC-OH on guinea pigs has been shown to be much greater than the effect of TCE when measuring depression of the spinal reflex and electrical excitability of the cerebral motor cortex.[4] It has also been shown that ethanol potentiates and attenuates the effects of TCE as determined by EEG measurements.[5] Grandjean found that by exposing rats to 400 ppm of TCE for 8 hours per day, 5 days a week for 44 weeks, TCE did not affect learning or intelligence in rats but decreased their "neuromuscular efficiency."[6]

In humans, TCE has been reported to cause EKG changes of disturbed sympathetic nerve control in as many as 1/3 of the subjects tested. Arryhthmias and even cardiac arrest are reported when using TCE as an anesthetic. EEG effects and reversible memory disturbances have been reported in cases of acute TCE poisoning.[7] Optical disturbances such as decreased general vision, constriction of visual field, and diminished optokinetic fusion were reported in human volunteers exposed to 1,000 ppm of TCE for 2 hours.[8]

Chronic exposure to TCE can lead to contact dermatitis and chemical burns of the skin, cornea, and conjunctiva. TCE is a potent irritant of the upper respiratory tract and can cause slight to moderate emphysema. Macrocytic anemia has been associated with some cases of intoxication. In high doses, TCE causes narcosis, with an initial excitatory phase. Stewart and his associates exposed 10 human volunteers to 100 and 200 ppm of TCE for time periods ranging from 1 hour to a 5 day work week.[2] At 200 ppm, untoward subjective responses were mild, inconsistent, and of doubtful significance. There was, however, sensations of mild fatigue and sleepiness in 5 subjects during the 4th and 5th consecutive days at an exposure level of 200 ppm of TCE. The following biological tests were performed on the subjects and found to be normal: C.B.C., E.S.R., total serum lipid, total serum protein, serum electrophoresis, SCOT, SGPT, urinalysis for urobilinogen, TC-OH, and TCA. Also normal were the results of the Romberg test, heel-to-toe, finger-to-nose, Crawford manual dexterity, and Flanagan coordination and inspection tests.

Chalupa and his associates report that the greatest implication for adverse behavioral responses to acute exposures of TCE is in predisposing an individual to an accident.[7] Minor post-intoxication symptoms are headache, vertigo, and insomnia. Memory may be affected for a year or more following acute high level exposure to TCE, especially as measured by mechanical memory tests.

Salvini and his associates exposed 6 human subjects to 110 ppm of TCE for two 4-hour periods separated by an 1 1/2 hour resting interval.[9] Subjects were tested with a perception test using tachistoscope presentation, the Eschsler Memory Scale, a complex reaction time test, and a manual dexterity test. Statistically significant decreases in performance by the subjects were noted on all tests, with decreases being greater on the more complicated tests. Salvini concludes that since the TCE exposures were close to the threshold limit value (TLV) of 100 ppm for the compound, it is possible that exposures at the TLV level may well be capable of adversely affecting psychophysiological efficiency.

Toluene is a milder central nervous system depressant than is trichloroethylene. Toluene produces mild fatigue, weakness, confusion, and paresthesia of the skin at 200 ppm for eight hours of exposure. At higher concentrations, extreme fatigue, mental confusion, nausea, headache, and dizziness occur. Exposures to levels of 50 to 100 ppm have repeatedly failed to cause any effects.[10]

Very little literature on the effects of n-propyl acetate on man is available. The compound is similar to other simple esters, causing mild skin and mucous membrane irritation and mild central nervous system depression at levels considerably above 200 ppm.[11]

IV. HEALTH HAZARD EVALUATION

A. Initial Visit - Observational Survey

On September 1, 1972 NIOSH investigator Melvin T. Okawa conducted an observational survey of the Western Electric Company plant in Dublin, California. Representatives of management present during the observational survey were Mr. ~~C.E. Leslie~~, Assistant Manager Personnel Labor Relations, Mr. ~~W.W. Heinze~~, Plant Engineer, and Mr. ~~A.R. Pike~~, Safety Engineer. Representing the employees were Mrs. ~~Karilynn Gliedon~~ and Mrs. ~~Helen Consiglio~~ (International Brotherhood of Electrical Workers, AFL-CIO Local 2342).

Plant Process - Conditions of Use:

The printed wiring board processing area was designated in the hazard evaluation request as the section of the plant where exposures to solvent vapors were occurring. Here, printed wiring board units undergo a series of hand and mechanical soldering, fluxing, spraying, and washing operations before they are ready for final distribution.

First, the board units are sent through an automatic mass solder machine (see figure 1). The soldering and washing steps are automatic, and the operator is responsible for introducing and removing the board units. Flux is applied, and the units continue on a conveyor through a solder "waterfall" and a trichloroethylene wash. One employee can operate the machine and two of them are in the general area. For the most part, the mass solder machine is enclosed and local exhaust ventilation is provided at the TCE wash point. However, it would not be considered as a closed system, and TCE vapors can escape into the atmosphere. At the end of each shift, the operator is responsible for cleaning the mass solder machine. During an operation that takes about 20 - 30 minutes to complete, the worker soaks a rag with TCE and wipes over most of the surface area of the machine. Once a week, the cleaning operation is more thorough, and the cleaning time is extended to one hour. Protective gloves are worn by the worker, but respirators are not. The operator is generally at the machine for an entire shift, but it does not run continuously. The day's supply of board units regulates the length of time

the machine is in operation.

The board units are taken out of the processing area and undergo a series of modifications in the back assembly area before they are returned. The units are brought to the two spray booths in the processing area. The booths are positioned at the east and west sides of the facility (see figures 2 and 3). On the east side, an additional spray booth was being installed for future use. The worker loads four board units into a holder, sprays them with a lacquer (n-propyl acetate and toluene), and unloads them onto a large drying rack. The drying rack is illustrated in figure 2. The spray booths are equipped with local exhaust ventilation and the worker is required to wear an organic vapor respirator. Because of the existing control measures, worker exposure to solvents seemed minimal. However, spray booth operators remove their respirators frequently as there are break periods between fresh racks of board units, and they receive exposure to ambient levels of solvents. It takes these workers about 10 - 15 minutes to complete a rack of board units.

A washing or cleaning booth is located next to each of the spraying booths. With a brush dipped in TCE, the worker scrubs and cleans the board units inside the hood. The TCE is contained in a small pan and is replenished from a safety container located in the hood (see figure 4). Each washing booth is equipped with local exhaust ventilation and the worker is required to wear an organic vapor respirator. TCE vapors become airborne because the solvent is readily splashed outside of the hood when the worker becomes careless. Vapors also become airborne from the units left in the drying racks since they are not dried for a long enough period inside the hoods. Because of the control measures, workers are exposed to minimal amounts of TCE while they are using the hood. However, like spray booth operators, these employees remove their respirators during the frequent break periods between fresh racks of board units.

The board units are then sent to the testing area for inspection. Some of the testers are seated at tables located 15 - 20 feet from the booths and drying racks (see figure 3). The majority of complaints concerning solvent vapors are voiced by employees in the testing area. By interviewing these employees, it was discovered that drying racks can accumulate between the booths and the testing area. The employees feel that they suffer more symptoms whenever the drying racks accumulate in the area. Approximately 10 employees work in the front sections of the testing area for a full shift.

B. Environmental Evaluation

An environmental survey for airborne concentrations of trichloroethylene, n-propyl acetate, and toluene was conducted on three separate days (September 13, December 7, 1972, and February 16, 1973) by NIOSH investigator Melvin T. Okawa.

Personal breathing zone samples were collected with MSA Model G battery powered vacuum pumps which were used to draw air through special glass sampling tubes containing activated charcoal. The sampling method using charcoal tubes for solvents was developed by NIOSH. The pumps were hooked to the worker's belt and the charcoal tube was attached to his lapel. The sampling rate was maintained at 1.0 liters per minute and the sampling times ranged from 10 - 22 minutes in length. Workers were told to perform their jobs normally, and representative samples were collected.

After the sample was collected, the charcoal tube was sealed and sent with the others to NIOSH laboratories in Salt Lake City, Utah. Analysis of the charcoal was performed by the standard analytical method developed by NIOSH. The solvents were desorbed from the charcoal with carbon disulfide, and an aliquot of the solution was injected into a gas chromatograph. Solvent concentrations were assayed from the recorded curve.

Results:

The results from the environmental surveys of the Western Electric plant are contained in Table 1 and summarized in Tables 2 and 3.

Nine breathing zone samples were collected on employees spraying board units with a lacquer containing n-propyl acetate and toluene. The NPA concentrations ranged from nondetectable (0) to 32 parts per million (ppm) and the toluene levels were between 0 - 12 ppm. The average concentrations for NPA and TOL respectively were 15.2 and 6.0 ppm. Although spray booth operators were not working with trichloroethylene (TCE), the levels ranged from 13 - 40 ppm (average concentration 25.3 ppm) in the 9 samples collected. Since respiratory protective devices are mandatory while spraying, these solvent levels do not represent the true worker exposure. The levels would represent work exposure without respiratory protection and with continuous spraying. Regardless of the conditions of the exposure, the levels of NPA and TOL do not present health problem to the spray booth operators. The TCE levels were slightly higher, but evidence from past research indicate that the concentrations would not constitute a health hazard. The mean values or levels of TCE by type of operation is summarized in Table 3 for the day of February 16, 1973. On this day, NIOSH physicians visited the plant to collect urine specimens which were analyzed for TCE metabolite levels. Three samples were collected, and the average TCE concentration was 29.0 ppm. This value did not differ much from the overall average.

Twelve breathing zone samples were collected on employees washing board units with TCE. The NPA and TOL levels ranged from 0 - 6 and 0 - 2 ppm respectively. These levels were insignificant. The TCE concentrations were from 6 - 82 ppm (average - 39.0 ppm). The TCE

values represent exposure of wash booth operators while they are cleaning board units in the absence of respiratory protection. Since respirators must be worn by wash booth operators while they clean board units, the TCE levels do not represent a true exposure, but are an indication of the amount of TCE vapors that become airborne. Six samples were collected on February 16, 1973. The average TCE value was 48.3 ppm which did not differ from the overall average (39.0 ppm).

Twelve breathing zone samples were collected on workers in the testing area. The NPA and TOL levels ranged respectively from 0-21 and 0-6 ppm. These airborne levels were insignificant. TCE concentrations ranged from 8-44 ppm with an average of 24.4 ppm. Six samples were collected on February 16, 1973, and the mean level of TCE was 29.3 ppm. This value did not differ significantly from the overall average.

Six samples were collected on mass solder machine operators. Only a trace of NPA was found and TOL was not detected. TCE concentrations ranged from 23-87 ppm with an average of 44.0 ppm. Repeated human exposure to these levels of TCE are marked by an absence of any permanent adverse health effect. However, in view of the fact that the TCE bath is enclosed and ventilated, there is more TCE leakage than one would expect.

Four samples were taken while solder machine operators cleaned their equipment. NPA and TOL were not detected. TCE levels ranged from 30-106 ppm with an average of 70.5 ppm. In terms of the Federal standard, which is based on a time-weighted average over an eight hour day and a 40 hour week, these TCE levels are not excessive since workers clean their machines on the average for 20-30 minutes per day. One sample showed a level of 106 ppm of TCE. This value represents an excursion above the 100 ppm standard which is allowable as long as it is balanced by periods of exposure below the 100 ppm level. In terms of toxic effects, it is unlikely that workers would suffer any permanent adverse health effects from such a short-term exposure, but from the standpoint of sound industrial hygiene practice, the present cleaning procedure is not recommended. A less toxic solvent plus respiratory protection is recommended.

C. Medical Evaluation

On December 7, 1972 NIOSH physicians Drs. Bodner and Ellison interviewed 24 people working in the printed wiring board processing area to determine: (1) whether there was any consistency in the symptoms reported,

(2) incidence of complaints, and (3) seriousness of complaints. Of special interest was the incidence of weakness, nausea, vomiting, and other serious symptoms.

Of the 24 people interviewed, 22 were women and 2 men. Their ages ranged from 21 to 52 years with the mean and median at 37 years. All but three workers had some complaints about their working conditions. The numbers and the percentages of people who reported symtoms is listed below:

17	reported	nausea (70.8%)
13	"	headache (54.2%)
8	"	dizziness (33.3%)
6	"	throat irritation (25.0%)
6	"	nose irritation (25.0%)
6	"	fatigue and drowsiness (25.0%)
5	"	eye irritation (20.8%)
2	"	dermatitis (8.3%)
1	"	numbness (4.2%)
1	"	chest tightness (4.2%)
1	"	anorexia (4.2%)
1	"	abdominal pain (4.2%)

No one required hospitalization due to these symptoms, but 4 people saw either their own or a company physician or nurse. All the workers felt that their symptoms were relieved completely when they had left the work environment for several hours.

On February 16, 1973, NIOSH physicians Bodner and Polakoff returned to the plant for further medical studies. Eight hour urine samples were collected from 20 workers exposed to trichloroethylene and from 9 controls.

After being preserved with thymol and refrigerated, these samples were sent to NIOSH laboratories in Cincinnati, Ohio, and were analyzed on February 20 - 28, 1973. The specimens were analyzed for metabolites of trichloroethylene, trichloroacetic acid and trichloroethanol, by the method of Tanaka and Ikeda (British J. of Industrial Medicine, 25: 214, 1968). Creatinine was determined by the Autoanalyzer I standard method, a modification of the classic Jaffie procedure. Urine specific gravities were determined using a refractometer. Three hundred determinations were performed including standards and blanks. Urine specimens were treated before spectophotometry by the method of Frant and Westendorp (Archives of Ind. Hygiene and Occupational Med., 1: 308, 1950).

Results have been expressed in terms of milligrams (mg) of metabolite (TCA or TC-OH) per liter of urine corrected to a specific gravity of 1.024. Results reported in the literature as mg/l of a spot urine sample are not reliable because of the variation in urine concentration during the day. Results have also been expressed in terms of mg of metabolite per gram of urine creatinine. Correlation studies on the two reporting methods and their relationship to airborne TCE levels have not yet been completed.[12]

The time of the work week selected for the urine sample is important. In a recent study reported by Ogata and his associates, the rates of excretion of TCA and TC-OH were followed in humans exposed to 170 ppm of trichloroethylene in exposure chambers.[13] The authors conclude that TC-OH is rapidly excreted in urine following exposure and reaches a peak within 3 hours following exposure. On the other hand, TCA excretion does not reach a peak until 42 - 69 hours after exposure. Thus, TCA in Friday urines represents cumulative weekly exposure but not on the day sampled. However, TC-OH concentrations represents exposure during the day the sample was collected, and only residual excretion from exposure on previous days of the work week. Ogata and unpublished data from NIOSH have shown a linear relationship between air levels of trichloroethylene and urine TC-OH collected after the work day.[12,13] Urine samples were collected on a Friday.

Results:

Tables 4, 5, 6, and 7 summarize the data obtained from the analysis of urine samples collected from 20 exposed workers and 9 controls at the Western Electric Company plant. Control samples (Table 5) show values of TCA from undetectable to 29 mg/l or 24 mg/gram creatinine. TC-OH values show a range of undetectable to 27 mg/l or 18 mg/g creatinine. The lower level of detection is about 2 mg/l with considerable variation below 10 mg/l. Controls from a previous NIOSH health hazard evaluation (RHE 72-84) showed values for both metabolites averaging less than 2 mg/l. This finding indicates that control subjects at Western Electric had some exposure to TCE. The findings contained in Table 5 for post work samples where mean values for TCA and TC-OH were higher than pre-shift levels substantiates this conclusion. Also, from Table 5, control subjects with initials PP, AB, and LE were NIOSH personnel and all their pre-shift TCA and TC-OH urine levels were undetectable.

Table 4 contains the TCA and TC-OH values for exposed individuals. The data is summarized in Table 6. For exposed individuals, the range of TCA levels was 17 - 196 mg/l or 11 - 145 mg/g. The levels were elevated above the values found for the controls and were in the same general range as found in workers in the previous hazard evaluation conducted by NIOSH. The average pre-shift TCA level was 66.5 mg/l or 50.6 mg/g. The post work average was 70.6 mg/l or 53.1 mg/g. The post work average showed a slight jump, undoubtedly indicating the additional accumulation of TCA on Friday for the week. Trichloroethanol values ranged from 38 - 121 mg/l or 22 - 111 mg/g for pre-shift and 82 - 267 or 52 - 179 for post work levels. The respective pre-shift and post work averages were 78.1 mg/l or 58.4 mg/g and 137.0 mg/l or 103.2 mg/g. The TC-OH levels were elevated in the afternoon samples, indicating exposure to TCE during the day. The range of TC-OH values was generally less than those found in the previous hazard evaluation where TCE exposures were between 37 and 78 ppm on an 8 hour time-weighted average. This result would seem to indicate that on the average, workers at Western Electric were being exposed to slightly less quantities of trichloroethylene. Table 7 contains the ranges and means for TCA and TC-OH levels in high and low exposure groups. The high ex-

posure group was arbitrarily selected to include those workers who were handling trichloroethylene directly (spray booth, wash booth, and mass solder machine operators). The low exposure group was composed of workers in the testing and assembly areas. The ranges and means for TCA and TC-OH levels between the groups are different but may not be significantly different. On the average, levels are more for the high exposure group, indicating a greater exposure to TCE.

D. Conclusions

The environmental data substantiate the fact that overall levels of trichloroethylene, n-propyl acetate, and toluene in the printed wiring board unit processing area are well within the limits defined in the Federal standards and well below those levels generally thought to cause serious clinical symptoms and adverse health effects. The levels of n-propyl acetate and toluene in the atmosphere were not significant in terms of being hazardous to health. The airborne concentrations of trichloroethylene generally were less than 50% of the standard. Only one sample was collected where an excursion above the 100 ppm time-weighted average standard was recorded. This sample was collected during a short cleaning operation at the mass solder machine. Yet, from the medical interviews, a high proportion of similar symptoms which correspond well with those found from intoxication with TCE, NPA, and TOL or a combination of these agents was voiced by workers in the area. The biological data in the form of levels of urine metabolites of TCE indicated that workers were being exposed to TCE. At this time, no range of safe limits for urine metabolites of TCE have been established for an occupationally exposed population. The average urine trichloroethanol level of exposed persons at Western Electric correlate well with levels expected in workers being exposed to airborne concentrations of TCE below 50% of the Federal standard. From a previous NIOSH study, workers being exposed to TCE in a range of 37 - 78 ppm (based on an 8-hour time-weighted average) generally had higher urine trichloroethanol levels than those found in this investigation.

E. Toxicity Determination

Based upon the results of the investigation reported above, it is our determination that the substance trichloroethylene is toxic to workers in the printed wiring board unit operations at the concentrations and conditions used and found at the time of this evaluation.

Trichloroethylene is the only agent present is significant amounts throughout the work area and is thought to be the cause of the toxic manifestations of symptomatology occurring frequently in workers during periods of heavy usage, although environmental levels detected were below the current Federal standard.

The reported condition represents a hazard to the health of workers, although not considered serious since no permanent physical changes occur, and may also present the potential for a safety hazard due to the general reduction in motor function, ability to concentrate and increased likelihood of accidents on such occasions.

It is also judged that the substances, N-propyl acetate and Toluene, are not potentially toxic at the concentration used or found.

VI. RECOMMENDATIONS

1) All spraying and washing operations with printed wiring board units should be completed inside properly functioning ventilation hoods. Workers must avoid spilling solvents outside of ventilation hoods.

2) Approved respirators should be used at the spraying and washing hoods and a respirator maintenace program developed.

3) To minimize exposure to trichloroethylene by wiring board unit testers, keep freshly washed boards in the washing booth until fairly dry by collecting several boards in the booth and then transferring them to the large drying racks rather than transferring each of them separately immediately after washing.

4) All ventilation systems should be serviced regularly; frequent ventilation measurements should be made.

5) To minimize the exposure to trichloroethylene by mass solder machine operators, the ventilation system should be checked for adequacy of design, especially the capture velocities and the presence of leaks.

6) For washing mass soldering machines, a less toxic solvent should be substituted for trichloroethylene. Also, approved respirators should be worn by the operators during the cleaning operation no matter what the type of solvent used.

VII. REFERENCES

1) Browning, E., Toxicity and Metabolism of Industrial Solvents, Elsevier Publishing Company, London, 1965.

2) Stewart, R., Gay, Erley, Hake, and Peterson, "Observations on the Concentrations of Trichloroethylene in Blood and Expired Air Following Exposure of Humans, " American Industrial Hygiene Assoc. J., Vol. 23, March-April, 1962.

3) Kleinfeld, M. and I. Tabershaw, Archives of Ind. Hyg. & Occupational Med., 10: 134-41, 1954.

4) Mikiskova and Mikiska, "Trichloroethanol in Trichloroethylene Poisoning," Brit. J. Industrial Med., 23: 116, 1966.

5) Desoille, J. et al, "Intoxication experimentale aigue par le trichloroethylene," Arch. Mal. Prof., 23: 10-11, 1962.

6) Grandjean, E., "Trichloroethylene Effects on Animal Behavior," Arch. Environ. Health, 28: 106, 1960.

7) Chalupa, B. et al, "The Assessment of Electroencephalographic Changes and Memory Disturbances in Acute Intoxications with Industrial Poisons," Brit. J. Industr. Med., 17: 238, 1960.

8) Kylin, B. et al, "Effect of Inhaled Trichloroethylene on the CNS," Arch. Environ. Health, 15: July, 1967.

9) Salvini, M., Binaschi, S., and M. Riva, "Trichloroethylene in Combination with CNS Drugs," Arch. Environ. Health, 20: April, 1970.

10) Patty, F.A., Industrial Hygiene & Toxicology. Vol. II, Interscience Publishers, N.Y., 1967, pp 1226 - 1229.

11) Gleason, et al, Clinical Toxicology of Commercial Products, Baltimore, p 100, 1963.

12) Larry K. Lowry, PH.D., NIOSH, (unpublished report).

13) Ogata, et al, Br. J. Ind. Med., 28: 386, 1971.

Table I. Concentrations Of Trichloroethylene (TCE), N-Propyl Acetate (NPA), And Toluene (TOL) In Breathing Zone Samples Collected At The Western Electric Company Plant

Sample #	Location Of Sample	Date	TCE (ppm)*	NPA (ppm)	TOL (ppm)
9688	Spray Booth (west)	9/13	22.0	16.0	7.0
9700	"	9/13	40.0	32.0	11.0
10999	"	12/07	24.0	20.0	12.0
9691	Spray Booth (east)	9/13	24.0	9.0	3.0
9694	"	9/13	13.0	6.0	2.0
10996	"	12/07	18.0	13.0	6.0
11605	"	2/16	38.0	20.0	6.0
11608	"	2/16	17.0	N.D.**	N.D.
11611	"	2/16	32.0	21.0	7.0
9690	Wash Booth (west)	9/13	10.0	1.0	N.D.
9696	"	9/13	38.0	1.0	N.D.
10998	"	12/07	27.0	N.D.	N.D.
11002	"	12/07	82.0	N.D.	N.D.
11598	"	2/16	49.0	N.D.	N.D.
11600	"	2/16	41.0	N.D.	N.D.
11602	"	2/16	60.0	N.D.	N.D.
9692	Wash Booth (east)	9/13	16.0	6.0	2.0
9701	"	9/13	6.0	1.0	N.D.
11604	"	2/16	43.0	N.D.	N.D.
11607	"	2/16	44.0	N.D.	N.D.
11610	"	2/16	53.0	N.D.	N.D.
9693	Tester (west)	9/13	35.0	6.0	2.0
9699	"	9/13	9.0	6.0	N.D.
11003	"	12/07	19.0	N.D.	N.D.
11005	"	12/07	32.0	N.D.	N.D.
11599	"	2/16	19.0	N.D.	N.D.
11601	"	2/16	17.0	N.D.	N.D.
11603	"	2/16	16.0	N.D.	N.D.
9698	Tester (east)	9/13	14.0	1.0	N.D.
11000	"	12/07	8.0	21.0	6.0
11606	"	2/16	44.0	N.D.	N.D.
11609	"	2/16	40.0	N.D.	N.D.
11612	"	2/16	40.0	N.D.	N.D.
9689	Mass Solder	9/13	23.0	1.0	N.D.
9695	"	9/13	29.0	1.0	N.D.
10997	"	12/07	26.0	N.D.	N.D.
11613	"	2/16	39.0	N.D.	N.D.
11614	"	2/16	87.0	N.D.	N.D.
11615	"	2/16	60.0	N.D.	N.D.
9697	Cleaning Mass Sold.	9/13	99.0	N.D.	N.D.
11006	"	2/16	30.0	N.D.	N.D.
11007	"	2/16	47.0	N.D.	N.D.
11008	"	2/16	106.0	N.D.	N.D.

*ppm - parts of vapor per million parts of contaminated air by volume at 25°C and 760 mm of Hg pressure

**N.D. - compound was not detected in sample

Table 2. Ranges And Mean Values Of Trichloroethylene, N-Propyl Acetate, And Toluene Concentrations By Type Of Operation In Samples Collected At The Western Electric Company Plant*

Operation	No. Of Samples	TCE (ppm)	NPA (ppm)	TOL (ppm)
Spray Booth	9			
Range		13 - 40	ND - 32	ND - 12
Mean		25.3	15.2	6.0
Wash Booth	12			
Range		6 - 82	ND - 6	ND - 2
Mean		39.0	0.8	0.2
Testers	12			
Range		8 - 44	ND - 21	ND - 6
Mean		24.4	2.8	0.7
Mass Solder	6			
Range		23 - 87	ND - 1	ND
Mean		44.0	0.3	0.0
Cleaning Mass Solder	4			
Range		30 - 106	ND	ND
Mean		70.5	0.0	0.0

*abbreviations same as for Table 1.

Table 3. Mean Values Of Trichloroethylene By Type Of Operation In Samples Collected At The Western Electric Company Plant On February 16, 1973

Type Of Operation	No. Of Samples	TCE (ppm)
Spray Booth	3	29.0
Washing Booth	6	48.3
Testers	6	29.3
Mass Solder	3	62.0
Cleaning Mass Solder	3	61.0

Table 4. Concentrations Of Trichloroacetic Acid (TCA) And Trichloroethanol (TC-OH) In The Urine Of Workers Exposed To Trichloroethylene At The Western Electric Company Plant

Worker	Sample No.	TCA (mg/l)*	TC-OH (mg/l)	TCA (mg/g)**	TC-OH (mg/g)
W.G.	1 A***	108	103	67	64
"	1 B***	61	109	71	127
M.H.	2 A	62	106	47	80
"	2 B	53	238	34	153
R.F.	3 A	120	98	133	109
"	3 B	77	267	46	160
J.H.	4 A	27	38	23	31
"	4 A	27	89	27	90
A.W.	5 A	77	90	46	53
"	5 B	91	132	69	100
C.A.	6 A	77	67	71	62
"	6 B	49	140	38	110
J.N.	7 A	54	107	42	84
"	NO SAMPLE				
J.G.	8 A	57	81	79	111
"	8 B	84	116	77	107
B.L.	9 A	17	48	15	44
"	9 B	34	104	35	108
P.Q.	10 A	196	106	145	79
"	10 B	215	186	196	169
C.A.	11 A	60	51	26	22
"	11 B	86	82	54	52
V.A.	15 A	26	83	26	83
"	15 B	26	169	28	179
B.S.	16 A	53	95	25	44
"	16 B	97	131	66	89
J.G.	19 A	58	73	40	51
"	19 B	63	84	48	63
J.W.	20 A	27	83	11	33
"	20 B	78	126	46	75
P.F.	21 A	38	75	21	42
"	21 B	72	125	31	55
L.R.	22 A	74	51	55	38
"	22 B	67	153	39	90
F.E.	23 A	72	38	60	32
"	23 B	94	116	59	74
H.H.	28 A	94	121	57	74
"	28 B	46	125	31	84
R.T.	29 A	34	48	23	32
"	29 B	21	109	14	76

*mg/l - milligrams of metabolite per liter of urine corrected to a specific gravity of 1.024

**mg/g - milligrams of metabolite per gram of creatinine

***A/B - A is AM sample and B is PM sample

Table 5. Concentrations Of Trichloroacetic Acid (TCA) And Trichloroethanol (TC-OH) In The Urine Of Control Subjects Collected At The Western Electric Company Plant

Subject	Sample No.	TCA (mg/l)*	TC-OH (mg/l)	TCA (mg/g)**	TC-OH (mg/g)
J.Y.	12 A***	9	13	5	8
"	12 B***	8	27	5	18
P.P.	13 A	ND****	ND	ND	ND
"	13 B	ND	8	ND	5
L.L.	14 A	5	20	2	8
"	14 B	6	27	3	14
J.G.	17 A	5	15	3	9
"	17 B	4	18	3	15
M.J.	18 A	4	9	3	5
"	18 B	8	5	6	4
A.B.	24 A	ND	ND	ND	ND
"	24 B	17	ND	17	ND
N.A.	25 A	3	11	2	6
"	25 B	29	ND	24	ND
L.E.	26 A	ND	ND	ND	ND
"	26 B	3	ND	3	ND
V.B.	27 A	2	10	ND	7
"	27 B	18	ND	22	ND

*mg/l - milligrams of metabolite per liter of urine corrected to a specific gravity of 1.024

**mg/g - milligrams of metabolite per gram of creatinine

***A/B - A is AM sample and B is PM sample

****ND - the limits of detection are 2 mg/l and 2 mg/g. Values of 2 or less are indicated as ND (not detected). There is considerable variation for values of 10 or less

Table 6. Ranges, Means, And Standard Deviations Of Trichloroacetic Acid And Trichloroethanol Levels In Urine Samples Of Control And Exposed Subjects Collected At The Western Electric Company Plant*

Control Group	TCA (mg/l)	TC-OH (mg/l)	TCA (mg/g)	TC-OH (mg/g)
AM Samples				
Range	ND - 9	ND - 20	ND - 5	ND - 9
Mean	3.1	8.9	1.8	4.9
St. Dev.	2.9	6.9	1.6	3.5
PM Samples				
Range	ND - 29	ND - 27	ND - 24	ND - 18
Mean	10.3	9.4	9.2	6.2
St. Dev.	9.2	11.5	9.1	7.4
Exposed Group				
AM Samples				
Range	17 - 196	38 - 121	11 - 145	22 - 111
Mean	66.5	78.1	50.6	58.4
St. Dev.	41.1	25.5	36.0	26.2
PM Samples				
Range	21 - 215	82 - 267	14 - 196	52 - 179
Mean	70.6	137.0	53.1	103.2
St. Dev.	42.3	48.8	38.8	38.2

*abbreviations the same as for Table 5

Table 7. Ranges And Means Of Trichloroacetic Acid And Trichloroethanol Levels In Urine Samples Of High And Low Trichloroethylene Exposure Groups*

High Exposure (n=6)	TCA (mg/l)	TC-OH (mg/l)	TCA (mg/g)	TC-OH (mg/g)
AM Samples				
Range	58 - 196	73 - 106	40 - 145	51 - 109
Mean	103.5	96.0	79.7	72.7
PM Samples				
Range	61 - 215	84 - 267	34 - 196	63 - 169
Mean	93.3	169.3	77.3	128.7
Low Exposure (n=13)				
AM Samples				
Range	27 - 94	38 - 121	15 - 79	22 - 111
Mean	50.5	67.6	37.8	49.8
PM Samples				
Range	21 - 97	82 - 169	14 - 77	52 - 179
Mean	60.1	121.0	41.0	91.5

*abbreviations the same as for Table 6. High exposure group composed of employees working directly with solvents. Low exposure group composed of of employees in the testing and assembly areas.

Figure 1: Automatic Mass Solder Machine

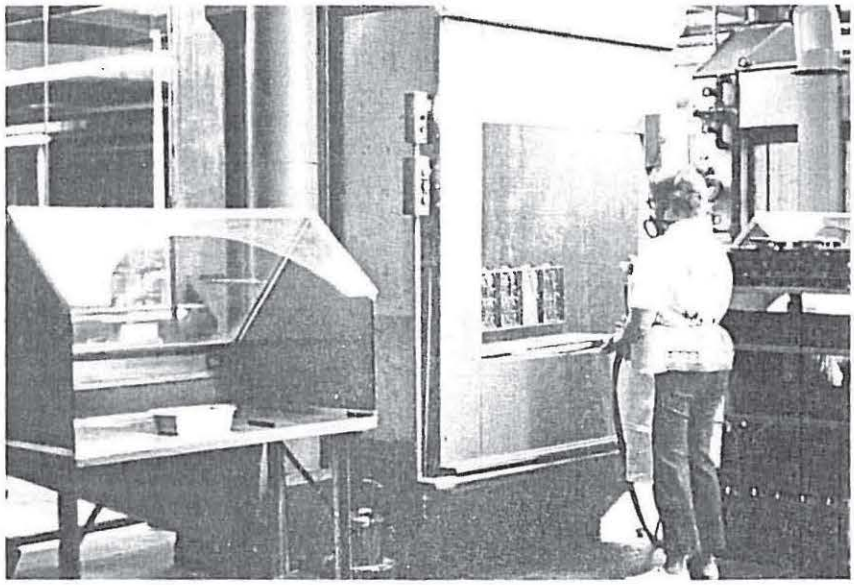

Figure 2: East Spray Booth and Drying Rack

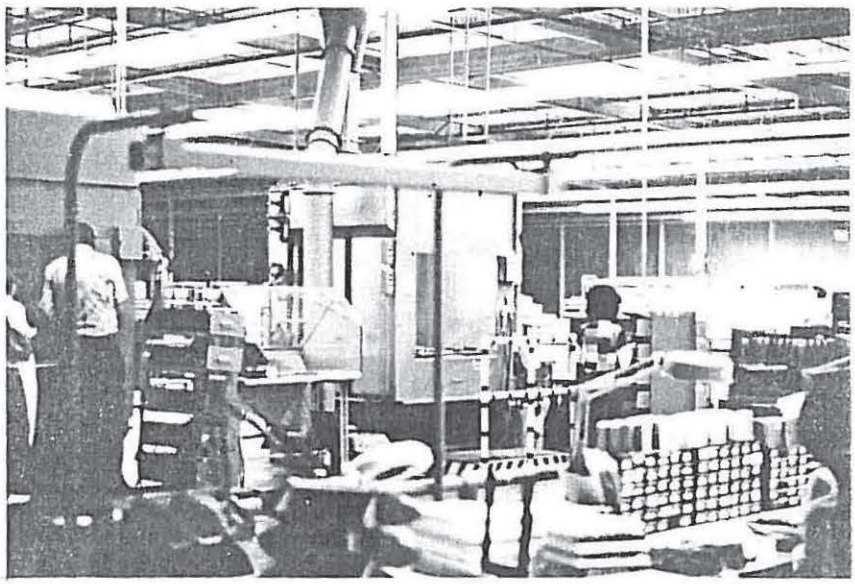

Figure 3: West Spray Booth

Figure 4: Safety Can From Which Small Pans Are Filled With Trichloroethylene