

HUMAN OCCUPATIONAL BEHAVIORAL TOXICOLOGY

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INTRODUCTION

The passage of the Occupational Safety and Health Act brought into action a program intended to help identify and prevent worker's exposure to occupational safety and health hazards. Implementation of this law has served to help increase public awareness of the possible deleterious effects of toxic substances found at the workplace. One needs only consider such examples as worker's exposure to asbestos (carcinogen), Kepone (neurologic and reproductive effects), or dibromochloropropane (male sterility) to realize the serious hazards posed by some industrial exposures. Clearly, the best means by which to reduce such occurrences is through a program of prevention. A necessary component of a prevention program is to detect early the functional effects of a toxic substance prior to the development of irreversible, pathologic damage. With regard to the nervous system, one approach to early detection of functional effects is through use of behavioral procedures. The use of methods and procedures from the behavioral sciences to detect the effects of toxic substances is called Behavioral Toxicology.

The purpose of this paper is to provide an overview of one aspect of behavioral toxicology, occupational behavioral toxicology. The content of this paper will therefore be restricted to investigations of humans exposed to chemicals of occupational relevance. In addition, the emphasis will be on human workplace investigations.

As stated previously, this paper will present an overview of occupational behavioral toxicology. As the term is used in this paper, occupational behavioral toxicology refers to human laboratory and workplace investigations, and for which the concern is the effect of industrial chemicals on behavior. Also, it should be understood that "behavior" is used in its broadest sense, i.e., can include: a) human performance on structured performance tasks; b) subject's responses on measures of subjective distress scales (e.g., personality inventories), or; c) observations made by clinicians of abnormal behavior. The intent of this paper is to acquaint the reader with the following: types of occupational behavioral toxicology studies, problems and limitations of such studies, and future directions for occupational behavioral

toxicology. For the interested reader, a more comprehensive description of occupational behavioral toxicology can be found in another source (Johnson and Anger, 1981).

The premise underlying the initial development of behavioral toxicology as a science was that impairment of behavior would be among the earliest indicators of an organism's response to a toxic substance. Early detection meant preventive action could be taken prior to the development of a pathologic condition. To an extent, the premise has proved to be valid - though by no means has the "early detection" of toxic damage been the outcome of all behavioral investigations. Nor has occupational behavioral toxicology yet become the end-all in providing a sensitive tool for use in preventive medicine. Human behavior is too complex for such a simplistic concept. Still, occupational behavioral toxicology, within its limits, has much to be commended for the study of workplace toxic substances. Some important uses of occupational behavioral toxicology include the following:

- a) In appropriately designed studies, as an indicator of functional impairment of the nervous system at toxicant exposure levels below those which produce overt tissue or organ damage;
- b) as a noninvasive means for monitoring the effects of worker's exposure to toxic substances;
- c) as a complement to neurological methods as a means of providing information about the central nervous system;
- d) as an indicator of impaired behavior that could compromise a person's safe job performance;
- e) as an indicator of worker's exposure levels to toxic substances that may require development of occupational standards.

In summary, occupational behavioral toxicology, while still in the developmental stage as a science, can provide the clinician or toxicologist with evidence of the functional effects of toxic chemicals, particularly those whose target is the nervous system.

HISTORICAL DEVELOPMENT

To appreciate the current status of behavioral toxicology, a historical review of this science will help provide a greater perspective.

The beginnings of what is now called behavioral toxicology occurred in the United States in the early 1960's. The initial interest in behavioral toxicology sprang from three sources. First, the study of the effects of drugs on behavior (behavioral pharmacology) had become relatively well accepted, and some behavioral investigators (Armstrong et al., 1963) saw the opportunity to use similar methods for the study of toxic industrial substances. Second, batteries of neuropsychological tests had been designed to evaluate organic brain damage and developmental behavioral disorders. A third, and

ultimately more important, factor in shaping the interest in behavioral toxicology was the need for government regulation of toxic substances in the community environment and at the industrial workplace. The public concern against environmental pollution grew, and this concern prompted Congress to create the mechanisms by which the Government would control potential exposures to environmental pollutants and toxic substances. Legislation such as the Clean Air Act, the Occupational Safety and Health Act, and the Toxic Substances Control Act provided the necessary legal basis for government agencies to investigate and establish exposure limits for toxic chemicals, plus the financial support to fund research efforts dealing with such problems.

Aided by the new interest of regulatory and standards settings groups, behavioral toxicology gradually began to grow. Work by Goldberg et al. (1962) on the behavioral effects of industrial solvents marked an early beginning. Later, Beard and Wertheim (1967) reported that human exposure to low concentrations of carbon monoxide impaired subject's performance on a laboratory task requiring auditory time discrimination. This report ultimately had a major impact on the establishment of a Federal air quality standard for carbon monoxide. The Beard and Wertheim study, because of its implications for regulatory actions, played a major role in the development of interest in behavioral toxicology in the United States and further stimulated funding of behavioral toxicology research by government agencies.

During the 1970's interest grew in behavioral toxicology along three fronts: 1) investigations of effects of toxic substances on operant behavior in laboratory animals; 2) human laboratory studies of effects of low concentrations of workplace chemicals on structured human performance tasks, and; 3) cross-sectional epidemiological and clinical studies of workers occupationally exposed to substances thought to adversely affect the nervous system and human behavior.

Of late, behavioral toxicology has progressed beyond simply obtaining information that may be useful in standards setting and regulatory action. Such information has been typically developed in studies of groups and, as such, is not easily applied to individuals comprising the group. The direction is now to develop additional behavioral tests that are predictive of early signs of toxicity, but which also permit interpretation for individuals, not just groups. The development of such tests will require standardized methods and norms for populations that are adjusted for sex, age, education and socioeconomic factors. While the task is formidable, progress toward that end is evident (Valciukas and Lilis, 1980).

TYPES OF STUDIES

The types of occupational behavioral toxicology studies have been grouped (Hanninen, 1981) according to the type of toxic effect expected, i.e., acute or chronic. Hanninen's classification is as follows:

1. Assessment of acute or subchronic effects
 - a) in experimentally induced exposures performed under laboratory conditions;
 - b) in workplace studies of occupationally exposed workers.
2. Assessment of the effects of long-term exposures
 - a) in prospective investigations of workers;
 - b) in cross-sectional analysis of relationships between worker's exposure levels and behavioral impairments, without the use of comparison groups;
 - c) in cross-sectional comparisons between groups of workers and a properly chosen reference group.

The type of occupational behavioral toxicology investigation chosen for implementation in a given situation will depend, of course, on the purpose of the study, the anticipated mechanism of toxicity of the toxic substances, and other factors. Illustrations of most of the aforementioned types of studies will be presented in a later section of this paper.

BEHAVIORAL METHODS

The specific behavioral methods utilized in a given investigation will be determined in large measure by the type of investigation being conducted. For example, human laboratory studies may be designed to examine in detail the effect of a toxic substance on one specific type of human behavior, e.g., performance on structured memory tests. Other types of investigations may choose to evaluate a broad range of behaviors, and as a consequence, a battery of behavioral tests would be administered.

Typical of the types of behavioral tests administered in occupational behavioral toxicology studies performed at the workplace are those found in the test battery developed at the Finnish Institute of Occupational Health (Hanninen and Lindstrom, 1976). The elements of this battery of tests are shown in Table 1. This particular battery has been used in more occupational behavioral toxicology investigations than any other. The functions being measured (e.g., memory/retention) are also shown in Table 1. A complete description of each test is beyond the scope of this paper, and the reader is referred to other sources (Hanninen and Lindstrom, 1976). Some brief comments, however, are in order. First, extensive use of tests from the Wechsler Adult Intelligence Scale (Wechsler, 1958) has occurred in occupational behavioral toxicology studies. These tests are attractive to the behavioral toxicologist for several reasons: 1) they possess normative data, which can sometimes be used for comparative purposes; 2) they are relatively easy to administer and do not require large amounts of time, and; 3) instrumentation requirements and scoring of results are not difficulties. As a general rule, these three considerations are desirable features for any behavioral test battery applied to groups of workers.

TABLE 1. ELEMENTS OF INSTITUTE OF FINNISH
OCCUPATIONAL HEALTH BEHAVIORAL TEST BATTERY
(HANNINEN AND LINDSTROM, 1976)

A. Wechsler Adult Intelligence Scale	B. Memory/Retention	C. Vigilance/Cognitive
1. Similarities	1. Wechsler Memory Scale	1. Bourdon-Wiersma Vigilance Test
2. Vocabulary	a. Logical Memory	2. Symmetry Drawing
3. Digit Span	b. Visual Association	3. Figure Identification
4. Digit Symbol	c. Associative Learning	
5. Picture Completion	2. Benton Visual Retention Test	
6. Block Design	3. Kuhnburg Figure Matching Test	
D. Coordination/Dexterity	E. Personality Variables	F. Self-Reported Symptoms
1. Santa Ana Dexterity	1. Rorschach Inkblot Test	
2. Finger Tapping	2. Eysenck Personality Inventory-C	
3. Mira Test		

SUBSTANCES STUDIED

A recent review (Johnson and Anger, 1981) of the literature pertaining to occupational behavioral toxicology identified approximately 30 reports describing workplace investigations. There are also approximately 30 reports on human laboratory studies of occupationally relevant chemicals.

Table 2 contains a list of industrial chemicals that have been studied for behavioral effects (Johnson and Anger, 1981). The type of behavioral study, human laboratory (L) or workplace (W), is also noted in Table 2. A review of Table 2 shows that about 20 chemicals have been the subject of occupational behavioral studies. Of this number, studies of the behavioral effects of industrial solvents have predominated. The reasons for this predominance are twofold: a) the widespread presence of solvents in industry, and; b) demonstrated toxicity on the central nervous system of these compounds at high exposure levels.

Shown also in Table 2 are those chemicals for which behavioral studies have influenced exposure limit recommendations found in NIOSH criteria documents. As indicated, results from occupational behavioral toxicology studies have influenced the recommendations found in several criteria documents.

TABLE 2. CHEMICALS THAT HAVE BEEN INVESTIGATED IN OCCUPATIONAL BEHAVIORAL TOXICOLOGY STUDIES

<u>SOLVENTS</u>	<u>METALS</u>	<u>PESTICIDES</u>	<u>OTHER</u>
Styrene (W)*	Lead (W)*	Organophosphates (W)	Carbon Monoxide (L, W)*
Carbon Disulfide (W)*	Mercury (W)*	Leptophos (W)	Anesthetic Gases (L)*
Methyl Chloride (L, W)			Polybrominated Biphenyls (W)
Xylene (L)			Jet Fuel (W)
Methyl Ethyl Ketone (L)			Formaldehyde (W)
Paint Sprays (W)			
Methylene Chloride (L)*			
Trichlorethylene (L)*			
Perchloroethylene (L)			
Toluene (L)			

L = Human Laboratory Study

W = Workplace Study

* = Permissible Exposure Limit (PEL) Impact

ILLUSTRATIVE STUDIES

It is beyond the scope of this paper to provide a review of the literature on occupational behavioral toxicology. Such a review is available elsewhere (Johnson and Anger, 1981). However, in order to illustrate the types of occupational behavioral toxicology studies that have been conducted, the following reviews are provided of investigations performed by NIOSH. The first study, a workplace carbon monoxide investigation, is an example of a workplace study for which the acute effects of a toxic substance were of concern to the investigators.

CARBON MONOXIDE (Workplace Investigation, Repeated Measures Design)

A review of the literature revealed only one workplace behavioral investigation of workers for which the investigator's principal concern was CO exposure. Johnson et al. (1974) studied the effects of vehicle emissions on the behavioral performance of toll collectors stationed at a busy interstate highway. Strictly speaking, the workers were not exclusively exposed to CO, but to other constituents of vehicle exhaust (e.g., lead, ozone) as well. The investigation, though, concluded that the major pollutant was CO. The group selected for study consisted of six workers employed as fare collectors at a toll highway in central Kentucky. The study group consisted of five females and one male. The subjects ranged in age from 19 to 49 years. All subjects were nonsmokers in order to eliminate this source of CO. The six workers were tested, three per day, on alternating days over a twelve day period.

Preceding the start, tests were administered prior to each worker's workshift and following completion of the workshift. Testing was conducted in motel rooms adjacent to the toll plaza where ambient CO levels were always less than 5 ppm. The performance tests consisted of the following: a) both simple and choice visual reaction time; b) hand-eye coordination, using the Michigan test; c) visual function (critical flicker frequency, pattern identification presented via a tachistoscope); d) an arithmetic test, and; e) a dual task. The experimenters controlled the difficulty of the dual task, and as its difficulty increased, the effect was to reduce subject's performance.

In addition to the behavioral tests, biological data (breath CO and COHb) and workplace industrial hygiene data (air lead, ozone, and noise) were also obtained. The investigators found that when preshift vs. postshift performance changes were correlated with increases in COHb due to workplace exposure, there were statistically significant ($p < .05$) associations between impaired dual-task performance as COHb increased. No associations between COHb and impaired performance on the other behavioral tests were found.

CARBON MONOXIDE (Laboratory Investigation)

The results from this study of toll collectors led to laboratory investigations of the acute toxic effect of CO on time-shared human performance. The experiment described below illustrates the utility of a laboratory study as a means of clarifying findings from workplace exposures. Given the limitations of the field investigation, e.g., only six subjects, how valid was the finding that CO would affect complex human performance under conditions where the subject's reserve performance capacity was decreased? To answer this question, Putz and colleagues (1976, 1979) designed a series of laboratory experiments that investigated the effects of CO on task time-sharing and vigilance. In two separate studies, using different experimental designs but identical performance tests, Putz et al. found that COHb levels as low as 5 percent degraded subject's performance on a time-shared task when the task performance was difficult. The degraded performance took the form of: a) increased time to respond to detect signals presented in the peripheral visual field, and; b) reduced accuracy on the psychomotor tracking task used concurrently with the peripheral field signal detection task.

The findings from the NIOSH studies on carbon monoxide show that acute CO exposures, at levels sufficient to yield 5 percent COHb, will degrade complex, demanding performance in humans unacclimatized to CO. The salient feature is that the subject's reserve capacity must be diminished by the task, that is to say, the performance must be difficult. What this suggests is that low level CO exposure will not affect worker's safe performance of routine, non-demanding jobs; however, it may affect performance of jobs requiring rapid response to complex situations.

LEPTOPHOS (Cross-Sectional, No Comparison Group)

In 1977 NIOSH was advised of 12 cases of serious neurological disease that had occurred in workers at a plant manufacturing Leptophos, a potent pesticide. Leptophos, though not approved for use in the U. S., was manufactured for sale in non-U. S. markets. Early in 1977, 155 workers (both current and former) were given comprehensive medical examinations that evaluated general medical status, neurological status, and measures of neuromuscular, ophthalmologic, psychological, and biochemical function (Xintaras et al., 1978). The following performance tests (and function tested) were administered to each participant: Santa Ana dexterity (hand-eye coordination), choice reaction time, Neisser Letter Search (visual organization), and three subtests from the Wechsler Adult Intelligence Scale (WAIS): Block Design (perceptual organization), Digit Symbol (memory efficiency), and Digit Span (recent memory). A complete occupational history was obtained for each worker. A comparison group was not included in this study, but rather, laboratory and literature norms were used for the various tests. Therefore, this study is an example of a cross-sectional behavioral study, but without the inclusion of a comparison group. Additionally, exposure and effect relationships were explored statistically within the study group. Results showed statistically significant ($p < .05$) performance decrements in Block Design, Choice Retention Time, and Santa Ana Dexterity. Since all three tests are strongly associated with peripheral nerve function, the investigators felt the performance decrements were suggestive of peripheral nerve dysfunction. There was some evidence, though not complete, from the neurological exams to support this hypothesis. A confounding factor in the interpretation of the results was the discovery that many workers had also been exposed to n-hexane, a potent neurotoxic solvent. The investigators were consequently unable to determine the causative agent in inducing worker's performance decrements. In this regard, the behavioral results were important in a clinical sense, since functional impairments in workers were identified. However, as a toxicology study, the association between cause and effect could not be established.

LEAD (Cross-Sectional, with Comparison Group)

As an example of a cross-section study, with use of comparison groups, Johnson et al. (1980) evaluated neurobehavioral functions and personality variables in 403 workers at a primary nonferrous smelter. Community residents not having a history of lead exposure served for comparison. Study groups of smelter workers were formed according to job title. Neurobehavioral tests consisted of visual choice retention time and hand-eye coordination. Personality variables were assessed using the Multiple Adjective Affect Checklist. Current PbB level and ZPP concentration were obtained for each study participant, as were occupational history, neurologic measures, and self-reported symptoms. The highest group mean

PbB was found to be 56 $\mu\text{g}/\text{dl}$ for male workers in the lead smelter. Analysis showed the smelter workers were about 10 percent slower in reaction time, but did not differ in hand-eye coordination. Using clinical norms, smelter workers were more depressed and hostile than unexposed workers.

FUTURE DIRECTIONS

It seems clear that occupational behavioral toxicology has contributed to a more complete understanding of the effects on workers of industrial hazards. It is also apparent that occupational behavioral toxicology, to be more useful, will require additional development. The nature of some of these future developments is the subject of this section.

SENSITIVITY

The ability of behavioral tests to detect, in a reproducible manner, small changes in central nervous system functions needs to be improved. Current test methods and procedures have been derived in large measure from standard tests, such as the Minnesota Multiphasic Personality Inventory and the Wechsler Adult Intelligence Scale, designed for more general purpose applications. There exists a need for development, and validation, of psychological tests that can be administered to worker populations exposed to low amounts of toxic substances. Of particular importance is the development of valid tests to evaluate the effects of toxic substances on: a) cognitive functions, and; b) personality factors. Presently used tests, such as the WAIS and the Eysenck Personality Inventory, were developed for clinical applications and, as such, do not possess the sensitivity to detect subtle changes in personality or cognitive functions.

The evaluation of sensory and psychomotor functions is more advanced than are tests of personality and cognitive functions. This results in large measure from the large body of literature on psychometrics. There is, however, a need to develop better normative data for the sensory and motor functions tests currently in use.

SPECIFICITY

The previously described NIOSH investigation of Leptophos (Xintaras et al., 1978) illustrates one limitation of occupational behavioral toxicology studies, namely, the lack of specificity of the behavioral tests employed in that study. Results from the aforementioned study showed functional impairment of the workers, but the investigators could not associate this impairment with a specific toxic agent. This lack of specificity is a problem common to many workplace investigations. Simply put, a number of toxic substances can yield the same pattern of behavioral impairment, using the behavioral tests currently employed in most worksite studies. From a toxicologic standpoint, this lack of specificity is unacceptable. What is clearly indicated is the need to develop behavioral tests that possess diagnostic and predictive specificity. The development of such tests would proceed primarily from laboratory studies, but would then require field evaluation and validation.

EFFICIENCY

In addition to improvements in sensitivity and specificity, there exists a need to improve the efficiency of behavioral tests used for workplace studies. As used here, efficiency refers to the time required for administration of the tests to each study participant, plus the experimenter's time to analyze the results. Presently used behavioral test batteries are inefficient in the sense that each subject's total testing time may approach 2 to 4 hours. While this amount of time, or longer, may be acceptable for many laboratory investigations, it often presents a problem for workplace studies, especially those for which workers are being given time off the job for the purpose of biomedical evaluation. The need therefore exists for the development of behavioral test batteries that tap a range of behaviors, but do not unduly impose a time-to-test burden on each participant.

SUMMARY

Occupational behavioral toxicology has contributed to our knowledge of the functional effects of a substantial number of industrial chemicals. This knowledge has been important in several instances in establishing permissible exposure limits for the workplace. Additionally, identification of impaired behavior has served as an early warning indicator of toxicity which, if left unaltered, may result in irreversible pathologic damage. There remains, however, a need to improve the sensitivity, specificity, and efficiency of behavioral test batteries currently used in workplace investigations.

REFERENCES

- Armstrong, R. D., L. J. Leach, P. R. Belluscio, E. A. Maynard, H. C. Hodge and J. K. Scott, (1963), "Behavioral Changes in the Pigeon Following Inhalation of Mercury Vapor", Amer. Ind. Hyg. Assoc. J., 24:366.
- Beard, R. R. and G. A. Wertheim, (1967), "Behavioral Impairment Associated with Small Doses of Carbon Monoxide", Am. J. Pub. Hlth., 57:2012-2022.
- Goldberg, M. E., C. Haun, and H. F. Smyth, Jr., (1962), "Toxicologic Implication of Altered Behavior Induced by an Industrial Vapor", Tox. Appl. Pharmacol., 4:148-164.
- Hanninen, H. and K. Lindstrom, (1976), "Behavioral Test Battery for Toxicopsychological Studies", Institute of Occupational Health, Helsinki, Finland.
- Hanninen, H., (1981), "Behavioral Methods in the Assessment of Early Impairments in Central Nervous Functioning", In: Biological Monitoring and Surveillance of Workers Exposed to Chemicals, Eds. A. Aitio, V. Riihimaki, H. Vainio. Hemisphere Publishing Company, New York, in press.
- Johnson, B. L., H. H. Cohen, R. Struble, J. V. Setzer, W. K. Anger and B. D. Gutnik, (1974), "Field Evaluation of Carbon Monoxide Exposed Toll Collectors", In: Behavioral Toxicology, Eds. C. Xintaras, B. L. Johnson, and I. DeGroot. National Institute for Occupational Safety and Health, Cincinnati, Ohio.

Johnson, B. L., J. B. Burg, C. Xintaras and J. L. Handke, (1980), "A Neurobehavioral Examination of Workers from a Primary Nonferrous Smelter", Neurotoxicology, 1:561-581.

Johnson, B. L. and W. K. Anger, (1981), "Behavioral Toxicology", In: Environmental and Occupational Medicine, Ed. W. Rom. Little, Brown and Company, Boston, in press.

Putz, V. R., B. L. Johnson, and J. V. Setzer, (1976), "Effects of CO in Vigilance Performance", National Institute for Occupational Safety and Health, Cincinnati, Ohio, (Report 77-124).

Putz, V. R., (1979), "The Effects of Carbon Monoxide on Dual-Task Performance", Human Factors, 21:13-24.

Valciukas, J. A. and R. Lilis, (1980), "Psychometric Techniques in Environmental Research", Environ. Res., 21:275-297.

Wechsler, D., (1958), The Measurement and Appraisal of Adult Intelligence, Williams & Wilkins Company, Baltimore.

Xintaras, C., J. B. Burg, S. Tanaka, S. T. Lee, B. L. Johnson and C. Cottrill, (1978), "NIOSH Health Survey of Velsicol Pesticide Workers", National Institute for Occupational Safety and Health, Cincinnati, Ohio, (Report 78-136).

ACKNOWLEDGEMENT

The author is pleased to acknowledge the contributions of his colleagues, Drs. Kent Anger, Vernon Putz-Anderson, Charles Xintaras, and Mr. James Setzer, in the performance of the NIOSH investigations described in this paper. The typing of the manuscript by Mrs. Mary Swenk is gratefully appreciated.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFAMRL-TR-80-125	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PROCEEDINGS OF THE ELEVENTH CONFERENCE ON ENVIRONMENTAL TOXICOLOGY 18, 19, and 20 NOVEMBER 1980		5. TYPE OF REPORT & PERIOD COVERED CONFERENCE PROCEEDINGS
7. AUTHOR(s)		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of California, Irvine P.O. Box 3067, Overlook Branch Dayton, Ohio 45431		8. CONTRACT OR GRANT NUMBER(s) F33615-80-C-0512
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62202F, 6302, 01, 15
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE June 1981
		13. NUMBER OF PAGES 411
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
Behavioral Toxicology	Hydrocarbon Fuels	Genetic Toxicology
Pulmonary Physiology	Short-Term Exposure Limits	Carcinogenesis
Emphysema	Liquid Gun Propellants	
Oxidant Gases	Epidemiology	
Sensitization	Solvents	
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Subjects of presentations and discussions included behavioral consequences of exposure to occupational environments, development of emphysema after exposure to chemicals, epidemiology of industrial solvents and genetic factors in susceptibility to environmental agents. The toxic effects of specific fuels and chemicals used by the Armed Forces were also discussed.		

AFAMRL-TR-80-125



**PROCEEDINGS OF THE ELEVENTH CONFERENCE
ON ENVIRONMENTAL TOXICOLOGY
18, 19, AND 20 NOVEMBER 1980**

*UNIVERSITY OF CALIFORNIA, IRVINE
OVERLOOK BRANCH, P. O. BOX 3067
DAYTON, OHIO 45431*

JUNE 1981

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