

TECHNICAL BULLETIN

OCCUPATIONAL HEALTH

**GUIDELINES FOR EXPOSURE PREVENTION, MEDICAL  
SURVEILLANCE AND EVALUATION OF WORKERS WITH THE  
POTENTIAL FOR EXPOSURE TO 2,4,6-TRINITROTOLUENE (TNT)**

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HEADQUARTERS, DEPARTMENT OF THE ARMY

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TECHNICAL BULLETIN  
MEDICAL TNT 297

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TO 2,4,6-TRINITROTOLUENE (TNT)**

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## CHAPTER 1

### INTRODUCTION

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#### **1-1. Purpose and scope**

*a.* This bulletin provides guidance and procedures to prevent occupational exposures of munitions workers to 2, 4, 6-Trinitrotoluene (TNT) and to identify and assess potential exposures of workers through medical evaluation and surveillance. It provides installation and medical staff specific guidance on—

(1) Toxicity of TNT that includes identification of the potential adverse health outcomes associated with TNT exposure.

(2) Medical surveillance that includes appropriate medical examinations (pre-placement, periodic, exposure, and termination), and identifies workers who have an increased risk for adverse health outcomes associated with TNT exposure.

(3) Exposure prevention.

*b.* This bulletin implements for TNT munitions workers the policies, procedures, and services prescribed by Army Regulation (AR) 40-5, Department of the Army Pamphlet (DA Pam) 40-11, and DA Pam 40-503 for the prevention and mitigation of occupational illness and injury, as part of the Army Occupational Health (OH) Program.

*c.* The appropriate elements of exposure prevention and medical evaluation and surveillance specified in this bulletin, as determined by the local medical authority in coordination with the U.S. Army Materiel Command (USAMC) and U. S. Army Installation Management Command (USAIMCOM) surgeons, will be addressed in the language of the contracts for Government-Owned, Contractor-Operated (GOCO) and Contract-Owned, Contract-Operated (COCO) munitions operations. All changes in contracts should be reviewed by local contracting officers.

#### **1-2. References**

Appendix A provides a list of required and related references.

#### **1-3. Explanation of abbreviations and terms**

The glossary contains a list of abbreviations and terms used in this publication.

#### **1-4. Roles and responsibilities**

*a.* The Surgeon General—

(1) Provides oversight to ensure that TNT exposure hazards are identified on all USAMC installations and that appropriate measures to protect the health of workers are recommended.

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(2) Coordinates with the USAMC surgeon, USAIMCOM surgeon and the U.S. Army Joint Munitions Command (USAJMC) surgeon to implement recommendations.

*b.* The U.S. Army regional medical center (USAMEDCEN) commander or the commander of the servicing USAMEDCEN or U.S. Army medical activity, as the local medical authority—

(1) Ensures that the chief of preventive medicine, occupational health physician (OHP) or other physician is designated to support the OH Program at each installation where TNT is handled. (See AR 40–5, para 2–18q).

(2) Communicates with the USAMC surgeon on a periodic basis to assess effectiveness of exposure prevention, surveillance, and mitigation procedures.

(3) Ensures OH clinics implement these guidelines.

(4) Coordinates with the USAIMCOM surgeon to ensure OH clinics on USAIMCOM installations are aware and follow the guidance provided within this document.

*c.* The installation commander (at sites that have employees and/or processes where TNT exposure is possible) ensures that—

(1) All employees participate in a TNT prevention, medical surveillance, and evaluation program conforming to the requirements of this document.

(2) The criteria and procedures published in this document are applied and implemented at Government-Owned, Government-Operated; COCO; and GOCO operations, as specified in the language of the GOCO contracts. The language in TNT production GOCO/COCO contracts will specifically provide for the exposure prevention, medical surveillance, and evaluation of workers with potential and actual exposure to TNT according to applicable Occupational Safety and Health Administration (OSHA) standards as well as the criteria and procedures provided in this document.

(3) Supervisors and workers are informed of the health risks associated with TNT and are aware of the administrative and engineering controls in their work areas.

(4) Engineering and administrative controls are adopted to ensure that exposure to TNT is kept below the levels established in this document.

*d.* The designated OHP—

(1) Implements and manages the OH program according to this document.

(2) Annually reviews the OH program and makes appropriate revisions based on the annual assessment.

(3) Coordinates with the installation commander, the installation safety manager, industrial hygienist, and, where appropriate, the contract officer's representative.

(4) Ensures that worksites/activities with potential occupational exposure to TNT are included in the Implementation Plan Master Schedule.

(5) Ensures that TNT workers receive education and training on symptoms of overexposure to TNT.

(6) Provides TNT health risk assessment and risk communication information to the installation commander, safety manager, supervisors, and workers.

(7) Reports to the installation commander and regional medical commander adverse outcomes related to TNT exposure.

(8) Recommends medical removal when worker exposure to TNT exceeds recommended levels.

*e.* The installation industrial hygiene (IH) program manager—

(1) Ensures that TNT worksites are incorporated in the IH implementation plan.

(2) Ensures IH sampling data and analyses will be provided to the OH clinic staff for inclusion in the employee's medical folder (EMF).

(3) Collaborates with the OHP, the installation safety manager, the installation commander, and supervisors on a regular basis by reviewing current exposure levels for TNT workers, the effectiveness of exposure controls, and the need for modifying administrative and engineering controls to reduce/eliminate ongoing exposures as well as highlighting risk communication needs.

*f.* The occupational health staff—

(1) Conducts initial, periodic, and termination medical surveillance for TNT-exposed workers according to the criteria and procedures specified in this document.

(2) Coordinates to maintain exposure and medical surveillance records on all workers.

(3) Evaluates workers following acute exposures with documentation in each EMF.

*g.* The installation safety manager—

(1) Assists supervisors investigate all accidents/incidents involving TNT exposure and record/report all occupational injuries and illnesses as required.

(2) Coordinates with the installation IH and the OH staff regarding worksite conditions and potential and actual exposures.

*h.* Work-area supervisors—

(1) Review and update department-specific standing operating procedures (SOPs) regarding the prevention of occupational injury/illness as needed but at the least, once every 3 years.

(2) Ensure that TNT workers receive education and training on: exposure; job-specific hazards; actions to eliminate, minimize, or report hazards; personal protective equipment (PPE); and procedures to report accidents, spills, and exposures.

(3) Verify and document staff competency in personnel competency-based files.

(4) Ensure that TNT workers participate in the local OH medical evaluation and surveillance program.

(5) Ensure that engineering and administrative controls, safe-work practices, and PPE are appropriate to the hazard, as well as functional, used, and effective.

(6) Report and help investigate all accidents/incidents involving TNT, and record/report all occupational injuries and illnesses as required.

(7) Inform workers of the health-related hazards and risks associated with TNT.

*i.* The TNT workers—

(1) Report potentially hazardous operations, conditions, and exposures.

(2) Comply with all procedures in this reference and in their department-specific safety SOPs.

(3) Properly use and maintain PPE.

(4) Follow administrative and engineering hazard controls.

**1-5. Technical assistance**

Requests for additional assistance and guidance may be addressed to Commander, U.S. Army Public Health Command (Provisional) (USAPHC (Prov)), ATTN: MCHB-TS-MOM, 5158 Blackhawk Road Aberdeen Proving Ground, MD 21010-5403 or by calling DSN 584-2464.

## CHAPTER 2

TOXICITY OF TNT

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**2–1. Background**

*a.* Physicians from the USAMC, the USAJMC, the Uniformed Services University of the Health Sciences, in coordination with the Occupational Medicine Program at the USAPHC (Prov) identified continued concerns regarding TNT occupational exposure as an area that would benefit from formal guidance.

*b.* The purpose of such guidance is to ensure that “best practices” are being applied to the occupational medicine support for Department of the Army (DA) installations involved with TNT-related production or processes.

**2–2. High-dose TNT exposure.**

High-dose TNT exposure occurs at levels significantly above the OSHA 8-hour time weighted average (TWA) permissible exposure limit (PEL) of 1.5 milligrams per cubic meter ( $\text{mg}/\text{m}^3$ ) of workplace air. Between 1914 and 1950, over 600 deaths and approximately 24,000 poisonings related to TNT exposure were reported in the United States.

*a. Toxic hepatitis.* TNT is documented to have caused workers’ deaths in the United States due to toxic hepatitis through the 1950s. Since then, exposure levels to TNT have decreased such that severe medical effects are rare if not nonexistent. Research in England from 1916–1942 noted a 26.3 percent rate of toxic jaundice among TNT-loading plant workers.

*b. Aplastic anemia.* This is a second-documented cause of TNT-related worker deaths in the United States through the 1950s.

**2–3. Moderate-dose TNT exposure.**

Moderate-dose TNT exposure occurs at levels below the current OSHA PEL and above the current American Conference of Government Industrial Hygienists (ACGIH<sup>®</sup>) threshold limit value (TLV<sup>®</sup>), an 8-hour TWA, of  $0.1 \text{ mg}/\text{m}^3$ , which is the Army-adopted exposure limit for its personnel. (ACGIH<sup>®</sup> and TLV<sup>®</sup> are registered trademarks of the American Conference of Governmental Industrial Hygienists.)

*a. Hemolytic anemia.* The exact pathophysiology of hemolysis related to TNT exposure is uncertain. Several mechanisms have been proposed including oxidative damage from the formation of free radicals in the mitochondria. Hemolysis seems to be a common effect from TNT exposures above the current 8-hour ACGIH TLV of  $0.1 \text{ mg}/\text{m}^3$ . While higher levels of TNT exposure may cause symptomatic hemolytic anemia, moderate to low exposure may cause an asymptomatic change in hemoglobin levels.

*b. Methemoglobinemia.* Methemoglobinemia has been noted with TNT exposure. Methemoglobin is different from normal hemoglobin because the iron in the heme groups has been oxidized to the ferric(+3) state rather than the ferrous(+2) state found in hemoglobin. Methemoglobin cannot bind oxygen resulting in an inability to deliver oxygen to tissues. A small amount of methemoglobin occurs naturally in the body (<1 percent). The major



biochemical pathway reducing methemoglobin to hemoglobin involves the enzyme cytochrome b5 (cyb5) reductase transferring electrons from nicotinamide adenine dinucleotide (commonly known as NADH) to methemoglobin. Methemoglobinemia can result from a congenital deficiency in cyb5 reductase or abnormal hemoglobins. These conditions are relatively rare. Most cases of methemoglobinemia are the result of an exposure to an oxidant drug, chemical, toxin, or smoking. Nitrites and aromatic amines, such as TNT, are also noted to cause this condition. Individuals are normally not symptomatic until methemoglobin levels are in excess of 20 percent. These symptoms include cyanosis, anxiety, headache, and dyspnea on exertion. At higher levels, cardiac arrhythmias, acidosis, coma, and seizures may occur. Methemoglobin levels above 70 percent are fatal.

*c. Cataracts.* The exact amount of exposure needed to cause cataracts is unknown. The TNT-related cataracts are typically located in the lens periphery and tend to be asymptomatic. Such findings may serve as a marker for TNT exposure.

*d. Liver (hepatocellular) damage.* At low to moderate TNT exposures, evidence of hepatocellular damage may be detected in the blood. Levels of lactate dehydrogenase and aspartate transaminase (AST) may become elevated before hematologic changes are detectable and at levels below  $1.0 \text{ mg/ m}^3$ . Higher rates of liver cancer have been reported among TNT workers in China.

*e. Other health effects.* Gastritis, nose/throat irritation, leukopenia, neuritis, heart muscle irregularities, decrease in sperm count, sperm abnormalities, and pancreatic dysfunction have been reported in some published studies.

## **2–4. Low-dose TNT exposure**

A low-dose exposure to TNT is an exposure level at or below the ACGIH 8-hour TLV.

*a. Hemolytic anemia.* Anemia can occur at TNT-exposure levels below  $0.5 \text{ mg/ m}^3$ . Exposure to TNT at these levels can cause a mild but significant decrease in hematocrit and hemoglobin levels. Increased reticulocyte counts and decreased haptoglobin (Hp) levels, often early indicators of hemolytic anemia may also be noted. These values normalize to baseline values within weeks for most TNT workers after removal from exposure. The long-term effect of low-dose TNT exposure on red blood cells and hematopoietic stem cells is unknown. Note that anemia, even mild anemia, secondary to exposure to an oxidizing substance such as TNT, is different from iron-deficiency anemia or anemia from blood loss. Any exposure to a chemical that has the ability to destroy red blood cells and damage hematopoietic stem cells must be taken seriously. A “no-observable effect level” (commonly known as NOEL) for TNT has not been established.

*b. Dermatitis.* Sensitivity to TNT may manifest itself as a rash or other skin manifestations. Typically, symptoms begin in sensitized employees within 3 months of exposure to TNT. Workers with significant and documented TNT sensitivity, either dermatologic or systemic, should be removed from TNT work.

*c. Cataracts.* The dose-response relationship for exposure levels of TNT and observed impairment of the lens is difficult to formulate since there are multiple routes of occupational exposure: inhalation, ingestion, skin, and corneal absorption. In a study done on 413 workers in

China, there was a positive correlation between the prevalence of cataracts and the duration of exposure. (See para 2–3c.)

*d. Long-term effects.* More long-term studies may be necessary to determine if there are chronic medical effects of long-term/low-dose exposure to TNT in humans.

*e. Animal studies.* Hepatomegaly, splenomegaly, and testicular atrophy have been reported in some animal studies.

## 2–5. Cancer association

Cancer association is assessed and reported by many agencies based on review of available studies and commissioned studies. The U.S. Environmental Protection Agency (USEPA) describes chemicals of greatest public concern within its Integrated Risk Information System (IRIS) toxic chemical database. Individual states may follow federal USEPA standards or have their own state USEPA agency. The World Health Organization’s International Agency for Research on Cancer (IARC) also evaluates and assigns carcinogenicity assessments.

*a.* The USEPA considers TNT to be IRIS Class C—possible human carcinogen based on inadequate evidence in humans and limited evidence in animal studies.

*b.* The IARC lists TNT as Group 3—not classifiable as to its carcinogenicity in humans (see <http://monographs.iarc.fr/ENG/Monographs/vol65/volume65.pdf>) based on inadequate evidence in humans and inadequate evidence in experimental animals.

*c.* The Office of Environmental Health Hazard Assessment of the California USEPA has listed TNT as a carcinogen in December 19, 2008. (See [http://www.oehha.org/Prop65/prop65\\_list/Newlist.html](http://www.oehha.org/Prop65/prop65_list/Newlist.html).)

*d.* Animal studies indicate that TNT is mutagenic. Tumor incidence included hepatocellular, renal urinary bladder hyperplasia, papilloma, transitional cell papilloma, and carcinoma of the urinary bladder in Fisher 344 rats (F344), which supports the conclusion that TNT is a carcinogen in F344 rats.

*e.* In hybrid B6C3F1 mice, when the incidence of all types of malignant lymphoma combined with lymphocytic leukemia were counted in all animal tissues rather than for a single organ, the incidence of tumors was not statistically significantly elevated nor was there a significant trend. Mutagenic activity was observed in *Salmonella* with and without metabolic activation. (See <http://www.epa.gov/ncea/iris/subst/0269.htm>.)

## 2–6. Absorption and properties of TNT

*a. Routes of absorption.* TNT can be absorbed through the skin, respiratory system (in both dust and vapor forms), and by ingestion. A lack of adequate protection from any of these types of exposures may increase the risk of developing adverse health outcomes. While the main route of exposure to TNT absorption varies between studies in the literature, it is clear that all routes of exposure are of concern. Absorption of TNT may vary based on the physical state of TNT, the type of TNT operation, and work practices of individuals and groups.

*b. Chemical and physical properties of TNT.*

(1) There is no evidence to suggest that the chemical properties of different types of TNT produced vary significantly. Recent chemical analyses performed at the Picatinny Arsenal have

revealed no major differences between TNT produced in Poland and TNT produced in Radford, Virginia (mid-1980s vintage).

(2) Tests performed included Fourier transform infrared spectroscopy testing as well as High-performance liquid chromatography. There may be some difference in physical properties between TNT from these two sources, and these characteristics could affect employee exposure at certain production sites.

For example, if a certain type of TNT consists of finer particles, which are more likely to become airborne if agitated, this could increase the risk of respiratory exposure to employees working with that type of TNT.

(3) There is currently no evidence showing that impurities in TNT or different mixtures have contributed to adverse medical outcomes.

## CHAPTER 3

MEDICAL SURVEILLANCE

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**3–1. Initial evaluation**

*a. Providers.* Clinical judgment should be exercised when conducting a TNT medical surveillance program. Occupational and environmental medicine specialists should oversee the development and implementation of such programs. The OHP should follow any specific guidance provided by the supporting U.S Army regional medical command and command surgeon. Their knowledge and experience of processes and medical surveillance at multiple facilities should be utilized.

*b. History and physical examination.* A comprehensive, pre-placement history and physical examination must be performed to identify any medical problems that would make the worker unable to work with TNT due to increased risk for adverse outcomes. Examples of this include, but are not limited to, chronic and uncompensated anemia, history of significant TNT hypersensitivity, and liver disease. A thorough history and physical examination are essential to assess a worker's potential risk for working with TNT. A sample TNT Worker Questionnaire is provided in appendix B and could be produced locally as a DA Form 4700 (Medical Record-Supplemental Medical Data) overprint and referenced in the Standard Form 600 (SF 600) Chronological Record of Medical Care. This sample TNT Worker Questionnaire should be in addition to required Department of Defense (DD) Forms 2807-1 (Report of Medical History) and DD Form 2808 (Report of Medical Exam). The OHP should also take into account the following:

- (1) Examples of medications which may impair liver function and potentially interact with TNT exposure include, but are not limited to, isoniazid, phenytoin, methotrexate, and statins.
- (2) Examples of other medical conditions or habits that may exacerbate, or be exacerbated by, TNT exposure can include, but are not limited to, the following:
  - (a) Glucose 6 phosphate dehydrogenase(G6PD) deficiency.
  - (b) Sickle Cell Anemia.
  - (c) Alcohol/illicit drug use associated with liver problems.
  - (d) Psychiatric problems or conditions which may adversely affect the reliability of the worker.
  - (e) Poor compliance with PPE and hygiene practices.

*c. Initial medical surveillance.* Initial medical surveillance (baseline) laboratories should include a complete blood count (CBC); reticulocyte count (RC); liver injury tests (consider using gamma glutamyl transpeptidase (GGT) as initial screen, and if positive, alkaline phosphatase (ALP); urinalysis with microscopic (UA w/micro) examination; and a baseline G6PD level. These laboratories, except the G6PD, should also be repeated at 30, 60, and 90 days after initial medical preplacement. The OHP should consider any additional studies, such as Hp levels, to clarify a worker's medical risk. Pregnancy screening should also be considered; there is insufficient information to determine whether pregnancy may put the worker at higher risk for TNT-related medical problems or to determine risk to the fetus.

*d. Early recognition of problems.* It is important that both the OHP and management work together to prevent workers with significant baseline laboratory or physical examination abnormalities from being exposed to TNT or other hazards, which could exacerbate an existing medical condition. Both the employee and management must be informed and counseled. If any significant abnormalities are identified at baseline, then the employee should be restricted from TNT operations and followed appropriately to document recovery. Workers with G6PD deficiency have an increased risk of hemolysis. With adequate PPE and/or engineering controls, G6PD-deficient personnel may still be able to work with TNT safely. They should be counseled concerning their risk and monitored closely.

### **3–2. Periodic evaluation**

*a. Periodic TNT medical surveillance.* After initial medical surveillance, periodic TNT medical surveillance should be performed every 90 days if the exposure to TNT is greater than 0.05 mg/m<sup>3</sup> 8-hour TWA. This value is half of the ACGIH TLV, which the Army has adopted as its exposure limit. More frequent surveillance every 30 days may be deemed necessary for new workers, workers new to a process, work areas of concern, and workers of concern (such as, poor compliance with PPE and hygiene, sites with increased duration of exposure due to longer work shifts, or when the OHP has noted a pattern of anemia among exposed workers). The OHP will determine appropriate medical surveillance intervals after collaboration with safety, IH, management, and the RMC Occupational Medicine Consultant/ U.S. Army Joint Munitions Command (USAJMC)/USAMC Surgeons.

(1) If any significant laboratory abnormalities are identified, the OHP must review the employee's medical history and exposure history, examine the employee as necessary, and determine if the laboratory abnormality is most likely due to TNT exposure. If the abnormality is secondary to TNT exposure, the worker should be removed from TNT operations and followed appropriately to document recovery. Management and the worker must be appropriately informed and counseled. An investigation should be conducted to determine if an overexposure occurred, and why it occurred.

(2) If there is an overexposure, corrective measures need to be taken. Workers with significant laboratory abnormalities should not return to TNT work until their laboratories have normalized, and they have been cleared to return by the OHP. For workers with laboratory abnormalities not considered to be TNT related, the OHP should determine if continued work with TNT would likely aggravate the underlying cause. Consultation with the employee's private physician may be necessary. Examples of TNT-worker findings that would indicate the need for removal from TNT work are—

(a) Hemoglobin level that has decreased below normal laboratory values or has dropped more than 1.9 millimoles per deciliter (mmol/dL) from baseline and/or a hematocrit that has decreased below normal laboratory values or has dropped more than 2.9 percent from baseline.

(b) Reticulocyte count > 2 percent.

(c) Skin discoloration—yellow or orange skin—may serve as a sign of dermal TNT overexposure and should be evaluated thoroughly by the OHP.

(d) Discolored urine (see “Urinalysis” 3–2e(3)).

(e) Cataracts may indicate TNT exposure. Evidence of cataracts should prompt additional evaluation. There is insufficient evidence to suggest that cataracts associated with TNT exposure impair vision. Routine screening for cataracts is not recommended.

(f) Significant elevation of liver function tests (GGT and ALP).

(g) TNT contact dermatitis.

*b. Return to TNT work.* If a worker has been removed from TNT work for over 6 months and is scheduled to return to work involving TNT, then the OHP should consider performing a medical examination, including physical examination and laboratory assessment, to ensure fitness for duty to rebaseline the individual for periodic assessment and to consider monthly surveillance laboratories for 90 days. It is essential that an employee returning to TNT work be enrolled in an appropriate TNT medical surveillance program.

*c. Laboratory testing.* The following are general guidelines relating to laboratory testing for periodic medical surveillance. Laboratory studies should include hemoglobin and hematocrit (H&H), RC, Hp levels, UA w/micro, and a liver injury test. (Consider using as initial screen, and if positive, then ALP.) (See para 3–2e(2).)

*d. Medical restriction.* Workers with anemia or other medical conditions, places them at a higher risk from TNT exposure; they should be temporarily removed from TNT work. The employee should not be returned to TNT operations until the anemia, and/or other health problem has resolved, and he/she is cleared by the OHP. Permanent exclusion should be considered if the anemia does not resolve or if there are other chronic medical conditions that might be exacerbated by TNT exposure. Management may remove workers for other issues, such as noncompliance with PPE or hygiene processes. Consider work restrictions for pregnant employees.

*e. Abnormal laboratory tests and recommended actions.*

(1) Anemia. For the purposes of TNT surveillance, anemia is defined as a decrease in both H&H below established normal ranges for the supporting laboratory. For routine surveillance, the H&H may be used and abnormal results or trending results, followed-up with a CBC as well as consideration of increasing frequency and scope of testing. A TNT-related anemia is typically normocytic (mean corpuscular volume within established normal range). The anemia also tends to be hemolytic at low to moderate doses.

(a) The RC elevation or rising levels could indicate a period of compensated hemolysis prior to developing measurable anemia.

(b) The Hp levels drop with hemolysis. It may be an earlier indicator than a rise in RC since the RC presumably drops later in the exposure if there is any degree of aplasia.

(c) Other tests, such as liver enzymes and urinalysis, may support the diagnosis of TNT exposure or rule out/in other causes.

(d) Laboratory criteria that could suggest an anemia is related to TNT exposure include—

1. Reticulocyte count increased above normal ranges, in the presence of anemia, as an indication of compensatory red cell production.

2. A peripheral smear or manual count revealing spherocytes, schistocytes, and Heinz Bodies, supporting the diagnosis of hemolytic anemia.

(e) Medically removed workers may return to work upon resolution of their anemia and receiving education regarding the health effects of TNT exposure and personal protective measures. Attempt to identify the source of exposure, and ensure it is mitigated, to the extent possible, prior to returning the affected worker to work. Guidance for exposure investigations is included in para 4–4.

(2) *Tests for liver injury.* Most of the commonly ordered “liver function tests,” such as the transferase enzyme activities, measure liver injury rather than liver function (see Department of Defense (DoD) 6055.05-M, C4.10). None of the commonly available liver-injury tests are particularly sensitive for chemical injury; GGT is the most sensitive, at about 45 percent, followed by alkaline phosphatase at 27 percent and alanine transaminase (ALT) at 20 percent. The ALP elevation has nearly 100 percent specificity for positive biopsies in chemical workers’ livers; ALT is in the high 80-percent range, and GGT in the low 80-percent range.

(a) The ALP and GGT are superior to ALT and AST for detecting chronic low-level liver injury as might occur with TNT exposure. The GGT and ALT are superior to ALP for detecting acute (high-dose) chemical liver injury. Although GGT has a high sensitivity, it also has a high false-positive rate (5–15 percent), resulting in a poor positive predictive value.

(b) Approximately 23 percent of males, age 30–39 years, have ALT values above the laboratory upper limit of normal. The best explanation for this relates to the fact that most “normal ranges” are developed using small samples (20–30 values) and assumptions that the distribution of values will be normal. Much research points to the fact that normal ranges (especially for ALT) should be done nonparametrically using large samples (150+). Most clinical laboratories do not go to this effort.

(c) Usually, the purpose of monitoring the liver is to detect unrecognized, chronic exposures. Occasionally, workers are monitored after a known or likely acute overexposure. High level, acute exposures have a higher prevalence of liver injury; therefore, the physician can have more confidence in an abnormal test result. In low level, chronic overexposures, the prevalence of disease is less, so interpreting abnormal test results is more difficult.

1. For a single test for chronic exposure, consider ordering just a GGT. Sequential testing can be done using the GGT as a screening test; if it is abnormal, then it can be confirmed with an ALP.

2. Consider the occupational history, exposure information, and PPE use with abnormal tests. Restriction away from an industrial exposure for 30 days will often indicate if the causal entity is occupationally related.

(d) Because liver enzyme abnormalities are common in the healthy adult population, the OHP must not rely solely on these to detect or diagnose TNT exposure.

(3) *Urinalysis.* Any evidence of hematuria ( $\geq 3$ –5 RBC/high-power field (HPF)), greater than trace urobilinogen or moderate bilirubin levels may support the diagnosis of hemolysis. Pink or discolored urine from TNT exposure is not considered normal. The OHP should evaluate the employee for alternative explanations for the discoloration to include, but not limited to, hematuria and should consider additional tests that may assist in the evaluation.

*f. Special testing.*

(1) Excess TNT exposure. If excess exposure is suspected, draw normal surveillance laboratories plus an RC and order a manual differential on the CBC. A methemoglobin level should also be drawn. Other tests that may be useful in certain circumstances include: indirect bilirubin, direct antiglobulin test, iron, total iron-binding capacity, folate, B12, Hp, and G6PD levels. Consider consulting a hematology or gastroenterology specialist. Follow-up testing at 2, 4, and 8 weeks during TNT operations may be useful for monitoring worker health in the event of a significant exposure.

(2) Biomarker testing. The TNT metabolite dinitroaminotoluene (DNAT) in urine is associated with exposure to TNT. However, excretion rates exhibit large inter-individual, intra-individual, and temporal variability. Excretion also varies with route of exposure. Although DNAT testing can be performed at the Armed Forces Institute of Pathology, it is not recommended in most situations due to the following:

- (a) Urinary levels have no prognostic significance.
- (b) Excretion occurs at currently permissible TNT levels.
- (c) The DNAT levels do not correlate with anemia or other health effects. The DNAT results alone should not be used for work-removal determinations but should only be used to suggest the association between anemia (or other evidence of exposure) and recent TNT exposure.

(3) Methemoglobin measurement. Methemoglobinemia has been well documented after significant TNT exposure. Recently, technology has developed to enable noninvasive methemoglobin levels. Peak levels are normally noted 24 hours after a significant exposure. Monitoring of methemoglobin levels has not proven to be essential for routine TNT surveillance. It is an important part of the medical evaluation of anyone with signs/symptoms thought to be secondary to TNT exposure such as dark or rust-colored urine and unexplained fatigue.

### **3–3. Post-incident/exposure physical**

A post-exposure medical examination should be performed for any exposures or expected exposure over the ACGIH TLV within 24 hours following exposure. All signs and symptoms of exposure should be documented in the history and physical. In addition, a CBC with differential, liver enzymes, and urinalysis should be performed at a minimum.

### **3–4. Termination physical**

*a.* When an employee no longer occupies a position in which he/she is exposed to TNT, a termination physical should be performed within 30 days. If the periodic physical has been documented within the past 90 days, the examination is not required. This may be changed to more stringent requirements by the OHP for facilities, processes, or workers with higher exposure levels.

*b.* Documentation of an individual's state of health at the termination of exposure or employment is essential for comparison purposes if the employee later develops medical problems that could be related to occupational exposure. Termination physical requirements should be the same as those for a periodic physical.



*c.* The health clinic will forward copies of the health record to USAPHC (Prov) Occupational Medicine Program to track the cohort of former workers to monitor their health status over time. Records will be handled and stored so as to preserve the integrity of personally identifiable information and compliance with Health Insurance Portability and Accountability Act (HIPAA).

**3–5. Recordkeeping**

The OHP will ensure that the OH clinic implements a comprehensive program and maintains medical records that document the TNT medical surveillance program is carried out with the intent of this document. At a minimum, records will include—

- a.* Results of annual program assessments.
- b.* Results of IH workplace periodic exposure monitoring and documentation.
- c.* Workers’ medical records.
- d.* Annual review and approval of worker education and training records.
- e.* Workers’ employee medical file must be preserved and maintained according to Title 29, Code of Federal Regulation (CFR), Part 1910.1020(c) and (d).

## CHAPTER 4

EXPOSURE PREVENTION

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**4-1. Engineering controls**

*a.* Processes should be automated, enclosed, and under negative pressure when possible. Local exhaust ventilation (LEV) should be installed wherever there is the potential for any form of TNT release. As adverse health outcomes may occur at low-exposure levels, general ventilation may be needed to remove TNT not captured by LEV. Ventilation surveys should be conducted semiannually as well as processes where levels exceed  $0.05 \text{ mg/m}^3$  8-hour TWA quarterly. This is half the Army-adopted recommended exposure level of  $0.1 \text{ mg/m}^3$ , which is also the ACGIH TLV. Capture velocities are included in the initial design criteria for the LEV system. This documentation should be retained by the installation IH program manager for future reference. If design criteria are not available, velocities can be determined by referring to the ACGIH Industrial Ventilation Manual. Required capture velocities are based upon hood design, contaminant characteristics, distance from hood to source of contaminant release, and release velocity.

*b.* Some areas within TNT-production facilities have high ambient temperatures throughout the year. Increased sweating from seasonal temperature variation, strenuous work, and heavy coveralls may cause increased skin absorption of TNT. Environmental controls to cool the workplace are recommended to help minimize the impact of higher temperatures, especially during the summer months. There are commercially available systems that allow outside/make-up air to enter the building, which facilitates the removal of heat and contaminants while preventing drafts that are undesirable during certain TNT processes. The workplace temperature should be monitored and actions taken to protect workers based on data. Work-rest cycles should be based on ACGIH TLVs for heat stress.

*c.* Break/lunch facilities should include an area for washing up and changing clothes. This area must be separate from the lunch room. Restrooms should be conveniently located. The distance of the break/lunch facilities and the workplace must be carefully planned to balance safety requirements and convenience but not discourage employees from following good personal hygiene practices.

*d.* Effective IH environmental sampling is critical to evaluate existing engineering controls. An adequate number of samples need to be obtained from all major work areas over the entire work shift. Sample results need to be critically analyzed by the IH and medical specialists in order to best characterize the TNT hazard present. If sampling results are inadequate, more samples should be obtained to effectively determine a “best estimate” of the hazard. Wide ranges in TNT sampling results, both within specific work areas and overall, may reflect that existing engineering controls are inadequate.

**4-2. Work practices and administrative controls**

*a. General safety and personal hygiene.* Historically, TNT exposure has been controlled through general safety and hygiene measures. However, specific TNT controls may be

necessary. For example, a local hazard communication program, compliant with 29 CFR Part 1910.1200, shall instruct workers about the need for strict personal and shop hygiene and shall inform employees about the hazards of particular operations conducted in the individual plant. The program should emphasize the skin absorption of TNT as a major route of exposure.

*b. Protective clothing.* Employees exposed to TNT solids or dust or exposed to air concentrations at or above the ACGIH TLV, must completely change into clean (freshly laundered) protective coveralls with long sleeves before beginning work. A clean head cover must also be worn. Street clothes must not be worn under coveralls. The TNT workers must shower including washing hair and changing into clean coveralls before lunch as well as showering, to include washing the hair and changing back into street clothes at the end of the work shift. Strict adherence to thorough hand washing as well as the banning of eating, drinking, smoking, applying cosmetics, or using the toilet before showering, must be enforced.

*c. Job-site rotation.* Job-site rotation should be considered where exposure levels to TNT are considered high (such as, where engineering controls may be inadequate). Some installations have noted exposure problems when work shifts extend beyond the normal 40-hour workweek and above established hazard monitoring periods (for example, work shifts of 10 hours/day for 6–7 days a week). Management must be aware of the inherent risks of excess work scheduling for TNT operations. Short work shifts and increased worker rotations can help limit TNT exposure. The TNT-exposure limits are based on 8-hour shifts for 5 days a week and should be conservatively adjusted using the Brief and Scala formula for actual exposure durations (see Brief, R.S. and Scala, R.A. 1975).

*d. Changes to production schedule/process.* Installation OH and safety personnel should be particularly cognizant of significant increases in the production schedule or any major changes in the TNT-production process. These changes should receive an appropriate risk assessment to anticipate any potential increases in TNT-exposure levels or other factors that may overwhelm existing hazard controls.

*e. Segregation of TNT hazards.* Segregation of TNT hazards from workers and their Families is as follows:

(1) The TNT-contaminated work areas and clothing will be segregated from clean-showering and changing area.

(2) Installation will provide enough freshly laundered coveralls for workers to change a minimum of twice during a work shift. Laundry workers must also be protected from overexposure to TNT.

(3) The TNT-contaminated clothing will not leave the contaminated area of the worksite.

*f. Worker transfer.* Workers should not be transferred from a non-TNT job to a TNT-related job unless they are enrolled in an appropriate medical surveillance program.

*g. Eating in the workplace.* Eating food and chewing tobacco should not be allowed in or near a TNT workplace in order to prevent possible ingestion of TNT during a work shift. Water consumption should take place in areas properly segregated from TNT work areas and with appropriate hygiene practices.

*h. Housekeeping.* The TNT work sites should be kept clean. Floors and walls should be washed down frequently to prevent residual TNT build-up.

### 4-3. Personal protective equipment

*a. Physical and chemical hazards.* The PPE decisions must be based on specific physical and chemical hazards encountered and should be tailored to each area. At a minimum, employees assigned to the area should wear cotton coveralls, protective gloves, eye protection, and foot protection. In addition, hearing protection may be needed in designated areas. Since workers can become exposed to TNT via the dermal route, cotton coveralls should be tested periodically to ensure that laundering methods are effective at removing residual TNT from clothing. Webster's Reagent, which turns pink upon contact with TNT, is an effective means of testing for residual contamination.

Note: Webster's Reagent can be made as follows:

Saturate 100 milliliter of absolute ethyl alcohol with pellets of sodium hydroxide (NaOH), this may require 15+ gram (g) of NaOH. Continue adding pellets until no more will dissolve in the solution after vigorous shaking and stirring. Extra NaOH can be added to assure that the solution is saturated. A "working solution" is made by doing a 1:10 dilution of the stock solution with ethyl alcohol.

*b. Management, control, and use.* The management, control, and use of respirators will be conducted according to the policies and prescribed procedures in AR 11-34. Respirators should only be used as a temporary measure pending the installation/repair of engineering controls, not as a substitute for them. Respiratory protective equipment should be selected according to National Institute for Occupational Safety and Health (NIOSH) guidance (see NIOSH Technical Guide 87-116) and should be worn until exposure monitoring demonstrates effective engineering controls have reduced workplace exposures to below recommended levels for TNT. Only positive pressure, full-face respirators or power air-purifying respirators (PAPRs) with hoods are adequate if the respirator has to be worn more than 2 hours a day. High exposure levels, heat stress, and higher respiratory effort make negative respirators inappropriate for use all day. The power air-purifying respirator with hood is preferred in TNT operations where heat is a factor since they provide superior skin and respiratory protection while providing air flow over the face and neck. Full-skin coverage should be incorporated into PPE used in TNT operations where exposure levels are inadequately controlled by other methods. Some installations have successfully used tethered air lines for both better protection and for their inherent cooling effects. It is essential that a proper risk assessment be performed when considering the ideal respirator for any individual workplace.

*c. Employee training/education.* Employees must receive effective training on the hazards of TNT, symptoms of exposure, respiratory protection, PPE, and other OSHA-required training prior to the start of work in the facility. Hazard communication principles, including posting of signs of requirements for special precautions regarding work practices and PPE, should be addressed in worksite SOPs.

#### 4-4. Investigating exposures in workers

*a. Sentinel events.* Sentinel events for TNT exposure include aplastic anemia, methemoglobinemia, toxic hepatitis, elevated liver function studies, hematuria, dermatitis and/or yellow skin color, toxic neuropathy, trends in decline in hematocrit or hemoglobin, and/or an elevated RC.

*b. Overexposures.* All suspected and confirmed TNT overexposures must be evaluated to determine the cause of the exposure in order to prevent further overexposures. The unplanned exposure of personnel to TNT is technically an accident, and this should be reported and investigated through accident investigation channels to OSHA. The OSHA will order an investigation and may visit the site. Army, government or corporate authorities, as applicable, should conduct a formal investigation according to DA Pam 385-40 or governing policies. The OHP must work closely with IH, management, and the commander to determine the source of the exposure and to implement appropriate corrective measures.

*c. Case-definition-suspected TNT overexposure.* A suspected TNT overexposure is defined as an individual with confirmed direct exposure to TNT who had significant laboratory changes from their baseline without medical history or physical examination findings that would otherwise explain these findings. A suspected TNT-overexposure case must have at least one of the following:

(1) Hematuria ( $\geq 3-5$  RBC/HPF) greater than trace urobilinogen or moderate bilirubin levels with/without a report of rust or pink colored urine.

(2) Elevated GGT and ALP.

(3) Yellow/orange skin color attributable to TNT.

(4) Hemoglobin level that has decreased below normal laboratory values or has dropped more than 1.9 grams per deciliter (g/dL) from baseline, and/or a hematocrit that has decreased below normal laboratory values or has dropped more than 2.9 percent from baseline with/without leukocytosis or pancytopenia.

(5) Reticulocyte count  $> 2$  percent.

(6) Methemoglobin level  $> 3$  percent.

(7) Documented ongoing exposure to TNT confirmed by IH sampling while performing a job with risk of exposure to TNT.

*d. Case definition-confirmed TNT overexposure.* A confirmed TNT overexposure is defined as an individual with confirmed direct exposure to TNT who had significant laboratory changes from their baseline without medical history or physical examination findings that would otherwise explain these findings and whose abnormal findings resolve after removal from TNT exposure. A confirmed TNT overexposure case must have had at least one of the following:

(1) Hematuria ( $\geq 3-5$  RBC/HPF), greater than trace urobilinogen, or moderate bilirubin levels with/without a report of rust or pink colored urine.

(2) Elevated GGT and ALP.

(3) Yellow/orange skin color attributable to TNT.

(4) Hemoglobin level that has decreased below normal laboratory values or has dropped more than 1.9 g/dL from baseline and/or a hematocrit that has decreased below normal

laboratory values or has dropped more than 2.9 percent from baseline with/without leukocytosis or pancytopenia.

(5) Reticulocyte count > 2 percent.

(6) Methemoglobin level > 3 percent.

(7) Documented ongoing exposure to TNT confirmed by IH sampling while performing a job with risk of exposure to TNT.

#### **4–5. Production line closure recommendations**

*a.* If multiple workers develop anemia, methemoglobinemia, toxic hepatitis, or other signs of significant TNT exposure, the OHP should consult with IH and management to—

(1) Identify the route and source of exposure, keeping in mind that TNT is rapidly absorbed through intact skin.

(2) Determine the adequacy of engineering controls, work practices, administrative controls, and PPE.

(3) Determine the risk of further exposure.

*b.* If the risk of further exposure, despite all controls, remains significant, this suggests the need to close the production line until adequate controls can be implemented. In general, three or more health outcomes related to excess exposure within a month from a single production line should warrant consideration of production line closure until changes in production levels, work processes, engineering, administrative, or PPE controls can be implemented.

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**APPENDIX A****REFERENCES**

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**Section I****Required Publications**

Except as noted below, ARs and DA Pams are available online from the U.S. Army Publishing Directorate (APD) Web site: <http://www.apd.army.mil/>. American National Standards Institute (ANSI) standards are available online from the ANSI website: <http://www.ansi.org/library/overview.aspx?meniid=11>. The CFRs are available online from the Government Printing Office website: <http://www.gpoaccess.gov/CFR/index.html>.

**AR 11–34**

The Army Respiratory Protection Program. (Cited in para 4-3b.)

**AR 40–5**

Preventive Medicine. (Cited in para 1–1b, 1–4b(1).)

**AR 385-10**

The Army Safety Program. (Cited in para 4-4b.)

**AR 385-40**

Army Accident Investigation and Reporting (cited in para 4-4b.)

**DA Pam 40–11**

Preventive Medicine. (Cited in para 1–1b.)

**DA Pam 40-503**

Industrial Hygiene Program. (Cited in para 1-1b.)

**DoD 6055.05-M**

Occupational Medical Examinations and Surveillance Manual. (Cited in para 3-2e(2).)

**Title 29 CFR, Part 1910.1200**

The OSHA Hazard Communication Standard (HCS). (Cited in para 4–2a))

**Title 29 CFR, Part 1910.1020.**

The OSHA Access to employee exposure and medical records standard. (Cited in para 3–5e.)



**ACGIH**

Industrial Ventilation: A Manual of Recommended Practice, 25th Edition.  
ACGIH® Publication #2094 ISBN: 978-1-882417-52-0. (Cited in para 4-1a.)  
<http://www.acgih.org/store/ProductDetail.cfm?id=1905>

**NIOSH Technical Guide 87-116**

NIOSH Guide to Industrial Respiratory Protection. (Cited in para 4-3b.)

**Brief, R.S. and R.A. Scala.** 1975. Occupational exposure limits for novel work schedules, *American Industrial Hygiene Association Journal*, 36:467-469. (Cited in para 4-2c.)

**Section II**

**Related Publications**

A related publication is a source of additional information. The user does not have to read a related publication to understand this guidance. The CFRs are available online from the Government Printing Office website: <http://www.gpoaccess.gov/CFR/index.html>.

**DoD Instruction 6050.05**

DoD Hazard Communication (HAZCOM) Program

**DoD Instruction 6055.1**

DoD Safety and Occupational Health (SOH) Program

**AR 40-2**

Army Medical Treatment Facilities: General Administration

**AR 40-66**

Medical Record Administration and Health Care Documentation

**ANSI Z87.1-1989**

American National Standard Practice for Occupational and Educational Eye and Face Protection.

**ANSI Z358.1-2004**

American National Standard for Emergency Eyewash and Shower Equipment.

**Public Law 91-596**

Occupational Safety and Health Act of 1970.  
<http://www.usbr.gov/ssle/safety/PublicLaw91-596.pdf>

**Title 29 CFR, Part 1910.134**

Respiratory Protection.

**Title 42 CFR, Part 84**

Approval of Respiratory Protective Devices

**Section III**

**Prescribed Forms**

This section contains no entries.

**Section IV**

**Referenced Forms**

**DA Form 4700**

Medical Record-Supplemental Medical Data

**DA Form 2028**

Recommended Changes to Publications and Blank Forms

**DD Form 2807-1**

Report of Medical History

**DD Form 2808**

Report of Medical Exam

**SF 600**

Chronological Record of Medical Care

**Section V**

**Selected Bibliography**

Bolt H.M., G.H. Degen, S.B. Dorn, S. Plöttner, V. Harth. 2006. Genotoxicity and potential carcinogenicity of 2,4,6-TNT trinitrotoluene: structural and toxicological considerations. *Rev Environ Health*. Oct–Dec;21(4):217-28. (Available from the Institut für Arbeitsphysiologie an der Universität Dortmund (IfADo), Leibniz Research Centre for Working Environment and Human Factors, Dortmund, Germany.)

Charles R., M.D. Buck, and S. Edward Wilson, Jr. 1975. Occupational Health Special Study Project Control Number 32-049-75/76. Adverse Health Effects of Selected Explosives (TNT, RDX). January–November 1975. U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland. (Available from the U.S. Army Public Health Command (Provisional), Aberdeen Proving Ground, MD 21010-5403.)

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Letzel S, T. Göen, M. Bader, J. Angerer, T. Kraus. 2003. Exposure to nitroaromatic explosives and health effects during disposal of military waste. *Occupational Environmental Medicine*. 2003;60: 483-488. Institute for Occupational, Social and Environmental Medicine, University of Mainz, Obere Zahlbacher Str. 67, Germany.

Li, Kate et al. 2008. Evidence o the Carcinogenicity of 2,4,6-Trinitrotoluene. (Available from the Reproductive and Cancer Hazard Assessment Branch, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.)

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Li J, Q.G. Jiang, W.D. Zhong. 1991. Persistent ethanol drinking increases liver injury induced by trinitrotoluene exposure: an in-plant case-control study. *Hum Exp Toxicol*, Nov;10(6):405-9. Department of Occupational Health, School of Public Health, Beijing Medical University, China.

Liu HX, W.H. Qin, G.R. Wang, Z.Z. Yang, Y.X. Chang, Q.G. Jiang. 1995. Some altered concentrations of elements in semen of workers exposed to trinitrotoluene. *Occup Environ Med*. Dec;52(12):842-5. He-Nan Institute of Occupational Disease, Zheng-Zhou, China.

Liu YY, M. Yao, J.L. Fang, Y.W. Wang. 1995. Monitoring human risk and exposure to trinitrotoluene (TNT) using haemoglobin adducts as biomarkers. *Toxicol Lett*. May;77 (1-3):281-7. Institute of Occupational Medicine, Chinese Academy of Preventive Medicine, Beijing.

Morton AR, M.V. Ranadive, J.A. Hathaway. 1976. Biological effects of trinitrotoluene from exposure below the threshold limit value. *Am Ind Hyg Assoc J*, Jan;37(1):56-60.

Sabbioni G, R. Rumler. 2007. Biomonitoring of workers cleaning up ammunition waste sites. *Biomarkers*. Nov–Dec;12(6):559-73. Available from the Department of Environmental Health Sciences, School of Public Health and Tropical Medicine, Tulane University, New Orleans, LA 70112.

Sabbioni G, O. Sepai, H. Norppa, H. Yan, A. Hirvonen, Y. Zheng, H. Järventaus, B. Bäck, L.R. Brooks, S.H. Warren, D.M. Demarini, Y.Y. Liu. 2007. Comparison of biomarkers in workers exposed to 2,4,6-trinitrotoluene. *Biomarkers*. Jan–Feb;12(1):21-37. Institute of Environmental and Occupational Toxicology, Airolo, Switzerland.

Sabbioni G, Y.Y. Liu, H. Yan, O. Sepai. 2005. Hemoglobin adducts, urinary metabolites and health effects in 2,4,6-trinitrotoluene exposed workers. *Carcinogenesis*. Jul;26(7):1272-9. Epub 2005 Apr 7. Institute of Environmental and Occupational Toxicology, Casella Postale 108, 6780 Airolo, Switzerland.

Sabbioni G, J. Wei, Y.Y. Liu. 1996. Determination of hemoglobin adducts in workers exposed to 2,4, 6-trinitrotoluene. *J Chromatogr B Biomed Appl*. Jul 12;682(2):243-8. Institut für Pharmakologie und Toxikologie, Universität Würzburg, Germany.

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**APPENDIX B****SAMPLE TNT WORKER QUESTIONNAIRE**

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**B–1. Guidance**

Completion of this questionnaire on the part of the worker should help the healthcare provider understand any medical conditions that: (1) might interfere with biological monitoring, (2) might be consistent with other signs/symptoms of exposure to TNT. The results of the questionnaire should be maintained in the medical record and protected as required by HIPAA.

**B–2. Medical history**

This questionnaire assists the healthcare provider in obtaining a medical history that is essential for medical monitoring for TNT. This sample questionnaire asks basic questions to determine the nature and extent of exposure to TNT, the amount of PPE used, and if the employee has medical conditions that might put him/her at greater risk for TNT exposure or might explain abnormal laboratory values. This questionnaire also provides a basis for discussion between the employee and the healthcare provider to raise any questions or concerns they may have regarding work with TNT.

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**Sample TNT Worker Questionnaire**

The purpose of this confidential questionnaire is to determine issues that may affect your health if you are a TNT worker. It is very important that you complete it completely and truthfully. Positive answers alone will not be used as a basis for removing you from TNT work. Only abnormal laboratory values that indicate an over-exposure are used to determine if an employee should be removed from TNT work.

DATE: \_\_\_\_\_  
 NAME: \_\_\_\_\_ AGE \_\_\_\_\_ SEX: \_\_\_ male \_\_\_ female  
 BUILDING(s) where you work \_\_\_\_\_ WORK POSITION: \_\_\_\_\_  
 CURRENT MEDICAL PROBLEMS \_\_\_\_\_

**ALLERGIES to MEDICATIONS**

CURRENT MEDICATIONS (including herbal/natural products) \_\_\_\_\_

**MEDICAL HISTORY:** Do you have or have you ever had the following since your last TNT medical evaluation?

Anemia or other blood disorder	___ Yes ___ No	Diabetes	___ Yes ___ No
Bleeding problem	___ Yes ___ No	Thyroid Disease	___ Yes ___ No
Kidney Disease	___ Yes ___ No	Heart Disease	___ Yes ___ No
High Blood Pressure	___ Yes ___ No	Liver Disease	___ Yes ___ No
Peptic Ulcer	___ Yes ___ No	Skin Problems	___ Yes ___ No
Cancer	___ Yes ___ No		
Other	_____		

**Females Only:**

Could you be pregnant? \_\_\_ Yes \_\_\_ No  
 Do you have heavy bleeding between periods? \_\_\_ Yes \_\_\_ No  
 Do you use tobacco?  
 \_\_\_ cigarettes \_\_\_ snuff or chewing tobacco \_\_\_ other \_\_\_\_\_  
 How much alcohol do you drink on average per week? (number of 12 oz. beers, 5 oz. glasses of wine or 1.5 oz. of hard liquor)  
 \_\_\_ none \_\_\_ 1-6 \_\_\_ 7-12 \_\_\_ 13-24 \_\_\_ greater than 24

When was the last time you donated blood? \_\_\_\_\_

Since your last TNT exam, have you been?

Tired more than usual \_\_\_ Yes \_\_\_ No  
 Had shortness of breath \_\_\_ Yes \_\_\_ No  
 Headaches \_\_\_ Yes \_\_\_ No  
 Brown or blue lips \_\_\_ Yes \_\_\_ No  
 Red or Brown urine \_\_\_ Yes \_\_\_ No

Employee signature \_\_\_\_\_ OH Staff signature \_\_\_\_\_

Office Use only:

\_\_\_ Oxygen sat \_\_\_ Methemoglobin level \_\_\_ G6PD (baseline) \_\_\_ Hp  
 \_\_\_ Hgb \_\_\_ Hct \_\_\_ Differential results \_\_\_\_\_  
 \_\_\_ GGT \_\_\_ Alk Phos(ALP) \_\_\_ UA results \_\_\_\_\_

**Figure B-1. Sample TNT worker questionnaire**



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## APPENDIX C

## ADDITIONAL REFERENCE INFORMATION

**C-1. Carcinogenicity evidence**

Li, Kate et al. 2008. Evidence o the Carcinogenicity of 2,4,6-Trinitrotoluene. (Available from the Reproductive and Cancer Hazard Assessment Branch, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.)

(EXECUTIVE SUMMARY—)

*a.* 2,4,6-Trinitrotoluene (TNT) is one of the most commonly used explosives for military and industrial applications. It is valued because of its insensitivity to shock and friction, which reduces the risk of unexpected detonations. TNT exposure occurs occupationally during production and use and to the general public through contaminated drinking water, air, soil, foods, or otherwise coming in contact with TNT or TNT-contaminated media.

*b.* There are a small number of human studies. An ecologic epidemiological study reported elevated rates of leukemia in a German town where environmental exposures to TNT had occurred. The study was performed because of “an apparently high number of leukemias occurring in the town.” Living in the town was significantly associated with increased risks of both acute and chronic leukemia (Kolb et al., 1993). A population-based, case-control study in the same region of Germany hypothesized that the association in the ecological study was due to exposure to armament wastes. While leukemia was significantly associated with residing in one neighborhood bordering on an open drainage channel receiving wash water during a time of peak TNT production, the association was based on small numbers (just four cases and two controls exposed) (Kilian et al., 2001). Similar results were not seen for residences in other TNT-contaminated areas in the study, or for other measures of exposure to TNT. The investigators concluded that their results did not confirm the findings from the earlier ecologic study. A historical cohort study of TNT-exposed munitions workers in China reported a statistically significant increase in the rate of liver cancer (Yan et al., 2002), but this study had several significant methodological limitations that reduce the overall confidence that can be placed on study findings. Occupational exposure to TNT has caused liver toxicity and related mortality, and there are also some case reports of liver cancer from occupational exposure, as well as leukemia (e.g., Garfinkel et al., 1988; Yan *et al.*, 2002).

*c.* Two-year dietary studies on TNT carcinogenicity have been conducted in male and female Fischer 344 rats and B6C3F1 mice (Furedi et al., 1984a, 1984b). Hepatocellular hyperplasia but not cancer was elevated in male rats. In female rats, both benign and malignant neoplasms of the urinary bladder (transitional epithelia) were significantly increased in the high-dose group, and with a dose-related trend. This was accompanied by hyperplasia (transitional epithelia of the urinary bladder) providing further support that TNT was carcinogenic in the female rat bladder. In female mice, incidence of leukemia/malignant lymphoma in the spleen was significantly elevated in the high-dose group and with a dose-related trend. No significant carcinogenic findings were reported for male rats or mice. TNT is genotoxic in bacterial and mammalian systems *in vivo* and *in vitro*. It induced both frameshift and basepair substitution mutations in *Salmonella*, mutations in mammalian cells *in vitro* in the Chinese hamster ovary cell hypoxanthine phosphoribosyl transferase (CHO-HPRT) locus assay and the mouse lymphoma thymidine kinase (TK) locus assay. TNT induced oxidative DNA damage in rat sperm *in vivo*, as measured by increased formation of 8-oxo-7,8-dihydro-2'-deoxyguanosine (8-oxodG). The TNT metabolite 4-hydroxylamino-2,6-dinitrotoluene (4-NHOH-DNT) damaged DNA, increasing the formation of 8-oxodG and cleaving the DNA at sites with consecutive guanines (Homma-Takeda *et al.*, 2002). Several TNT metabolites have also been observed to be genotoxic in the *Salmonella* [2-amino-dinitrotoluene (2-ADNT); 4-amino-2,6-dinitrotoluene (4-ADNT); 2,6-diamino-4-nitrotoluene (2,6-DANT); 2,4-diamino-6-nitrotoluene (2,4-DANT)] and CHO-HPRT assays (4-ADNT; 2,6-DANT weakly positive). Urine from workers exposed to TNT has increased mutagenic activity in the *Salmonella* assay compared to that from unexposed workers.

*d.* TNT binds covalently to proteins in humans (hemoglobin (Hb) adducts) and animals (Hb adducts, liver proteins), indicating the potential to bind to DNA. TNT can be metabolized through multiple pathways to form

reactive nitroso species and reactive oxygen species, which may bind covalently with proteins and other macromolecules, induce oxidative stress, and oxidative DNA damage.

*e.* Structure activity comparisons with the carcinogenic nitrotoluenes 2,4-dinitrotoluene (2,4-DNT), 2,6-DNT, and 2-nitrotoluene (2-NT) suggest that common pathways of metabolism and similarities in the reactivity of metabolic intermediates with proteins and DNA exist for TNT.

*f.* Thus, there is evidence for the carcinogenicity of TNT, in the form of data on the development of benign and malignant tumors of the urinary bladder in female rats and hematopoietic tumors in female mice treated for two years by diet. Further evidence of potential carcinogenicity includes genotoxicity of TNT and metabolites in *Salmonella* and mammalian cells, as well as close structural similarity to 2-NT and 2,4- and 2,6- DNT, all three of which are carcinogenic and listed as such under Proposition 65. Human populations exposed to TNT have been inadequately studied with regard to carcinogenicity.

## C-2. Occupational health special studies

Charles R., M.D. Buck, and S. Edward Wilson, Jr. 1975. Occupational Health Special Study Project Control Number 32-049-75/76. Adverse Health Effects of Selected Explosives (TNT, RDX). January–November 1975. U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland. (Available from the U.S. Army Public Health Command (Provisional), Aberdeen Proving Ground, MD 21010-5403.) (ABSTRACT—)

*a.* A cross-sectional epidemiological study of 626 employees exposed to TNT, royal demolition explosive (RDX), or high-melting explosive (HMX) and 865 employees not exposed to explosives was conducted. All 1,491 employees were extensively evaluated for liver function and hematological abnormalities. Levels of worker exposure to both TNT and RDX were evaluated in the workplace. No significant liver function abnormalities were noted for exposed workers. Significant hematological abnormalities (mild anemia) were noted for TNT-exposed male workers.

*b.* The results of this study, in conjunction with previous studies and information in the scientific literature, indicate a need to lower the current standard for TNT exposure from 1.5 mg/m<sup>3</sup> to 0.5 mg/m<sup>3</sup>. Recommendations to lower this standard and to revise Army medical surveillance requirements for TNT workers are made.)

Hathaway, James A MD. 1977. Trinitrotoluene. A Review of Reported Dose-Related Effects Providing Documentation for a Workplace Standard. *Journal of Occupational Medicine*. Vol. 19, No 5.

(ABSTRACT—)

*a.* The scientific and medical literature on TNT was reviewed with emphasis on studies providing correlation between work exposures and adverse health effects. Numerous adverse effects including upper respiratory and gastrointestinal complaints, anemia, liver function abnormalities, and possibly aplastic anemia have been noted at TNT levels below the current standard of 1.5 mg/m<sup>3</sup>.

*b.* Mild biological effects, particularly reduction in hemoglobin levels or red blood cell counts, have been noted at exposures as low as 0.2 mg/m<sup>3</sup>. A workplace standard of 0.5 mg/m<sup>3</sup> as an 8-hour, time-weighted exposure is suggested for protection against adverse health effects.)

Sabbioni G, R. Rumler. 2007. Biomonitoring of workers cleaning up ammunition waste sites. *Biomarkers*. Nov–Dec;12(6):559-73. Available from the Department of Environmental Health Sciences, School of Public Health and Tropical Medicine, Tulane University, New Orleans, LA 70112.

(ABSTRACT—)

*a.* TNT is an important occupational and environmental pollutant. In TNT-exposed humans, notable toxic manifestations have included aplastic anemia, toxic hepatitis, cataracts, hepatomegaly, and liver cancer. Therefore,

it is important to develop protection measures and to monitor workers involved in the clean up of ammunition sites. Hemoglobin (Hb) adducts of TNT, 4-amino-2,6-dinitrotoluene (4ADNT) and 2-amino-4,6-dinitrotoluene (2ADNT), and the urine metabolites of TNT, 4ADNT and 2ADNT were found in 22–50 percent of the exposed workers but not in the control group.

*b.* The exposed workers were wearing protective equipment. The levels of erythrocytes, haemoglobin, creatinine, serum glutamic pyruvic transaminase, and lymphocyte levels were significantly lower in the exposed workers than in the nonexposed workers. The levels of blood urea and reticulocytes were significantly higher in the exposed workers than in the nonexposed workers. Headache (26 percent), mucous membrane irritation (16 percent), sick leave (18 percent), lassitude (8 percent), anxiety (6 percent), shortness of breath (3 percent), nausea (5 percent), and allergic reactions (8 percent) were reported by the exposed workers. In a further analysis, the U-4ADNT levels and the Hb-adduct levels were compared to the blood parameter and the health effects.

*c.* The blood parameters were not significantly different between the U-4ADNT positive and U-4ADNT-negative group. Headache, mucous membrane irritation, sick leave, lassitude, anxiety, shortness of breath, and allergic reactions were statistically not different between the two groups. Also in the workers with Hb-4ADNT adducts, no significant negative changes were seen regarding the changes of the blood parameters or the health effects. According to the results of the present study, it appears that the blood parameter changes and the health effects are more influenced by other factors than by the internal exposure to TNT.)

Sabbioni G, O. Sepai, H. Norppa, H. Yan, A. Hirvonen, Y. Zheng, H. Järventaus, B. Bäck, L.R. Brooks, S.H. Warren, D.M. Demarini, Y.Y. Liu. 2007. Comparison of biomarkers in workers exposed to 2,4,6-trinitrotoluene. *Biomarkers*. Jan–Feb;12(1):21-37. Institute of Environmental and Occupational Toxicology, Airolo, Switzerland.

(ABSTRACT—)

*a.* TNT is an important occupational and environmental pollutant. In TNT-exposed humans, notable toxic manifestations have included aplastic anaemia, toxic hepatitis, cataracts, hepatomegaly, and liver cancer. Therefore, methods were developed to biomonitor workers exposed to TNT. The workers were employed in a typical ammunition factory in China. The external dose (air levels and skin exposure), the internal dose (urinary metabolites), the biologically effective dose (hemoglobin adducts, urinary mutagenicity), biological effects (chromosomal aberrations and health effects), and individual susceptibility (genotypes of xenobiotic-metabolizing enzymes) were determined.

*b.* Hemoglobin (Hb)-adducts of TNT, 4-amino-2,6-dinitrotoluene (4ADNT) and 2-amino-4,6-dinitrotoluene (2ADNT), and the urinary metabolites of TNT, 4ADNT and 2ADNT, were found in all workers and in some controls. The levels of the Hb-adducts or the urinary metabolites correlated weakly with the skin or air levels of TNT. The urinary mutagenicity determined in a subset of workers correlated strongly with the levels of 4ADNT and 2ADNT in urine. The Hb-adducts correlated moderately with the urinary metabolites and with the urinary mutagenicity. The genotypes of glutathione S-transferases (GSTM1, GSTT1, GSTP1) and N-acetyltransferases (NAT1, NAT2) were determined.

*c.* In general, the genotypes did not significantly influence the Hb-adduct levels and the urine metabolite levels. However, TNT-exposed workers who carried the NAT1 rapid acetylator genotype showed an increase in urinary mutagenicity and chromosomal aberrations as compared with slow acetylators. The Hb-adduct 4ADNT was significantly associated with a risk of hepatomegaly, splenomegaly, and cataract; urine metabolites and genotypes were not associated with health effects. These results indicate that a set of well-selected biomarkers may be more informative regarding exposure and effect than routinely performed chemical measurements of pollutants in the air or on the skin.)

Sabbioni G, Y.Y. Liu, H. Yan, O. Sepai. 2005. Hemoglobin adducts, urinary metabolites and health effects in 2,4,6-trinitrotoluene exposed workers. *Carcinogenesis*. Jul;26(7):1272-9. Epub 2005 Apr 7. Institute of Environmental and Occupational Toxicology, Casella Postale 108, 6780 Airolo, Switzerland.

(ABSTRACT—)

*a.* TNT is an important occupational and environmental pollutant. In TNT-exposed humans, the notable toxic manifestations have included aplastic anemia, toxic hepatitis, cataract, hepatomegaly, and liver cancer. Therefore, we developed methods to biomonitor workers exposed to TNT. The workers were employed in a typical ammunition factory in China. The controls were recruited from the same factory. We determined hemoglobin (Hb) adducts and urine metabolites of TNT.

*b.* The Hb-adducts of TNT, 4-amino-2,6-dinitrotoluene (4ADNT) and 2-amino-4,6-dinitrotoluene (2ADNT), and the urine metabolites of TNT, 4ADNT and 2ADNT were found in all the workers and in a few controls. The 4ADNT was the main product. Although the levels of 2ADNT correlated well with 4ADNT, 2ADNT was not found in all the samples. Therefore, 4ADNT was the best marker of exposure for Hb-adducts and urine metabolites. The levels of the urine metabolites and Hb-adducts were related to the health status of the workers. The Hb-adduct 4ADNT was statistically significantly associated with risk of hepatomegaly, splenomegaly, and cataract. The odds ratio for cataract, splenomegaly and hepatomegaly were 6.4 [95 percent confidence interval = 1.4-29.6], 9.6 (1.1-85.3) and 7.6 (1.3-43.7), respectively.

*c.* No correlation was found between urine metabolites and health effects. These results were tested for confounding factors like age, workyears, smoker status, smoke years, cigarettes per day, and hepatitis B status using stepwise forward logistic regression analysis. In the case of splenomegaly, hepatitis B status is a confounder. In the case of cataract, age is a confounder. The Hb-adduct, 4ADNT, is a good biomarker of exposure and biomarker of biological effect.

Bolt H.M., G.H. Degen, S.B. Dorn, S. Plöttner, V. Harth. 2006. Genotoxicity and potential carcinogenicity of 2,4,6-TNT trinitrotoluene: structural and toxicological considerations. *Rev Environ Health*. Oct–Dec;21(4):217-28. Available from the Institut für Arbeitsphysiologie an der Universität Dortmund (IfADo), Leibniz Research Centre for Working Environment and Human Factors, Dortmund, Germany.

(ABSTRACT—)

*a.* Environmental contamination with TNT represents a worldwide problem. Concern for carcinogenicity can be derived from chemically related compounds, especially the dinitrotoluenes. In the metabolism of TNT, the reductive routes are preponderant. The main urinary metabolites of TNT are 4-amino-2,6-dinitrotoluene, and 2-amino-4,6-dinitrotoluene.

*b.* In humans exposed to TNT, the formation of hemoglobin adducts of the amino-dinitrotoluenes is in general concordance with the ratio of urinary excretion. The variations in quantities of excreted metabolites among the different occupational cohorts studied are likely explained by the different routes of exposure to TNT, including dermal uptake. Most studies show that urinary excretion of the amino-dinitrotoluenes (4-amino-dinitrotoluene plus 2-amino-dinitrotoluene) in a range of 1 to 10 milligrams per liter (-1) (5-50 micro M) are not uncommon—for instance in persons employed with the disposal of military waste.

*c.* Trinitrotoluene is mutagenic in *Salmonella typhimurium* strains TA98 and TA100, with and without exogenous metabolic activation. Mutagenic activity has been found in urine from workers who were occupationally exposed to TNT. An unpublished 2-year study was reported in 1984 by the Illinois Institute of Technology Research Institute, Chicago, Illinois. Fischer 344 rats were fed diets containing 0.4, 2.0, 10, or 50 mg/kg TNT per day.

*d.* In the urinary bladder, hyperplasia (12 of 47 animals  $p < .01$ ) and carcinoma (11 of 47 animals,  $p < .05$ ) were observed at significant levels in high-dose (50 milligrams per kilograms (mg/kg) (-1)) females and in one or two females, respectively, at 10 mg/kg (-1). Taking all the available evidence together, the appropriate precautions should be taken.)

Letzel S, T. Göen, M. Bader, J. Angerer, T. Kraus. 2003. Exposure to nitroaromatic explosives and health effects during disposal of military waste. *Occupational Environmental Medicine*. 2003;60: 483-488. Institute for Occupational, Social and Environmental Medicine, University of Mainz, Obere Zahlbacher Str. 67, Germany.

(AIMS—)

a. To investigate the exposure to dinitrotoluene (DNT) and trinitrotoluene (TNT) and the resulting effects in workers which occur during the disposal of military waste. METHODS: Eighty-two employees from a mechanical plant in Germany were studied, of whom 51 were regularly exposed to ammunition containing TNT and DNT, 19 occasionally, and 12 not at all. RESULTS: Air analyses yielded maximum concentrations of 20 micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ) for 2,4-DNT and 3250  $\mu\text{g}/\text{m}^3$  for 2,4,6-TNT, respectively.

b. The maximum concentrations in the urine of workers regularly exposed amounted to 5.0 micrograms per liter ( $\mu\text{g}/\text{L}$ )  $\mu\text{g}/\text{L}$  of 2,4,6-TNT, 1464.0  $\mu\text{g}/\text{L}$  of 2-amino-4,6-dinitrotoluene, 6693.0 of  $\mu\text{g}/\text{L}$  4-amino-2,6-dinitrotoluene, 2.1  $\mu\text{g}/\text{L}$  of 2,4-DNT, 95.0  $\mu\text{g}/\text{L}$  of 2,4-dinitrobenzoic acid, and 3.6  $\mu\text{g}/\text{L}$  of 2,6-DNT. There was a highly significant linear correlation between the urinary concentrations of the two main metabolites of TNT, 2-amino-4,6-dinitrotoluene and 4-amino-2,6-dinitrotoluene. In 63 persons TNT/DNT/metabolite concentrations above the analytical detection limit were found in urine.

c. These persons reported more frequently symptoms like bitter taste, burning eyes, and discoloration of the skin and hair than persons ( $n = 19$ ) without detectable TNT and/or DNT exposure. CONCLUSION: During the disposal of military waste containing relevant TNT and DNT, exposure can occur of occupational-medical relevance. Biological monitoring is suitable for the early detection of possible adverse effects at workplaces exposed to TNT. Protective measures should be improved, together with adequate occupational-medical surveillance of persons exposed to nitroaromatic explosives. Further studies are necessary to exclude possible long-term effects.)

Sabbioni G, J. Wei, Y.Y. Liu. 1996. Determination of hemoglobin adducts in workers exposed to 2,4, 6-trinitrotoluene. *J Chromatogr B Biomed Appl.* Jul 12;682(2):243-8. Institut für Pharmakologie und Toxikologie, Universität Würzburg, Germany.

(ABSTRACT—)

a. TNT is an important occupational and environmental pollutant. TNT can be taken up through the skin and by inhalation. It is, therefore, essential to have fast and reliable methods to monitor human exposure. In rat experiments, it has been shown that TNT binds covalently to blood proteins and to tissue proteins.

b. Hemoglobin (Hb) adducts of TNT are markers for the internal dose and possibly for the toxic effects of TNT (such as, cataracts). In the present paper, we introduce a new efficient method to quantify Hb adducts of TNT. Precipitated Hb was hydrolyzed with base in the presence of the surrogate internal standard 3,5-dinitroaniline (35DNA).

c. The released 2-amino-4,6-dinitrotoluene (2ADNT) and 4-amino-2,6-dinitrotoluene (4ADNT) were quantified against 35DNA by gas chromatography-mass spectrometry with negative-ion chemical ionization. The Hb of 50 workers and controls from a Chinese munition factory were investigated. The Hb-adduct levels ranged from 3.7 to 522 nanograms (ng) for 4ADNT and from 0 to 14.7 ng for 2ADNT per gram of Hb. However, in control samples from Germany no Hb-adducts of 4ADNT or 2ADNT could be found.

Liu HX, W.H. Qin, G.R. Wang, Z.Z. Yang, Y.X. Chang, Q.G. Jiang. 1995. Some altered concentrations of elements in semen of workers exposed to trinitrotoluene. *Occup Environ Med.* Dec;52(12):842-5. He-Nan Institute of Occupational Disease, Zheng-Zhou, China.)

(OBJECTIVES—)

a. A cross-sectional study was performed to find the concentrations of elements contained in the semen of workers exposed to TNT. SUBJECTS AND METHODS: Semen of exposed workers in two TNT plants located in He-Nan Province in 1992 were examined. RESULTS: The average TNT concentrations in the workplace, except the packing site, were found to have exceeded the maximal allowable concentration ( $1 \text{ mg}/\text{m}^3$ ); skin contaminations of male workers exposed to TNT were higher after a shift than in controls, and correlated with the total blood concentrations of TNT, 4-amino-2, 6-dinitrotoluene (4A), and 2-amino-4, 6-dinitrotoluene (2A).

b. Copper, zinc, sodium, magnesium, and selenium concentrations were significantly decreased, but potassium, calcium, cobalt, manganese, and lithium contents were not significantly changed in the semen of workers exposed to TNT. Compared with the control group, the percentage of liquifying time of semen, the sperm malformation

incidence, and viability in the men exposed to TNT were all significantly changed. CONCLUSIONS: Men exposed to TNT have decreased concentrations of some elements in semen and altered semen physiology.

Liu YY, M. Yao, J.L. Fang, Y.W. Wang. 1995. Monitoring human risk and exposure to trinitrotoluene (TNT) using haemoglobin adducts as biomarkers. *Toxicol Lett.* May;77(1-3):281-7. Institute of Occupational Medicine, Chinese Academy of Preventive Medicine, Beijing.

(ABSTRACT—)

*a.* Two studies were carried out in a TNT plant using TNT hemoglobin (TNT-Hb) adduct as a biomarker to study dose-adduct and adduct-response relationships. In the first study, TNT-Hb adduct levels were determined in 117 TNT-exposed workers in different working sites with different exposure conditions. External exposure was calculated from the inhaled air concentration plus skin contamination.

*b.* The TNT-Hb adduct levels in blood were significantly correlated with their external exposure to TNT. Two methods, high-pressure liquid chromatography with ultraviolet detector and competitive indirect enzyme-linked immunosorbent assay, were developed for measuring TNT-Hb adduct: good correlations ( $r = 0.77$  and  $0.86$ ) were found between these two methods. In the second study, TNT cataract was used as an indicator of health effects. The prevalence of cataract and the degree of lenticular damage increased with the increase of blood TNT-Hb level.)

Li Y, Q.G. Jiang, S.Q. Yao, W. Liu, G.J. Tian, J.W. Cui. 1993. Effects of exposure to trinitrotoluene on male reproduction. *Biomed Environ Sci.* Jun;6(2):154-60. Department of Occupational Health, School of Public Health, Beijing Medical University, China.

(ABSTRACT—)

*a.* A cross-sectional study was performed in two plants located in Henan Province in 1990 for observing the reproductive and sexual functions of male workers exposed to TNT. The TNT concentrations in the workplace air, except the packing site, were found to have exceeded MAC ( $1 \text{ mg/m}^3$ ).

*b.* The TNT-exposed male workers complained of more sexual disorders, such as impotence, the loss of libido, and sexual hypoesthesia than the control group. Compared with the control group, the volume of semen and percentage of motile spermatozoa were found to have significantly decreased, and the sperm malformation incidence increased significantly in TNT-exposed workers. The serum testosterone content in TNT-exposed male workers was significantly decreased as well.

Li J, Q.G. Jiang, W.D. Zhong. 1991. Persistent ethanol drinking increases liver injury induced by trinitrotoluene exposure: an in-plant case-control study. *Hum Exp Toxicol*, Nov;10(6):405-9. Department of Occupational Health, School of Public Health, Beijing Medical University, China.

(ABSTRACT—)

*a.* On the basis of a general survey conducted in a munitions plant, a case-control study was made on the various risk factors of liver damage induced by TNT exposure in the plant. One-hundred male cases with occupational TNT liver damage were paired with 100 male controls, one-by-one, for occupation, age and duration (years) of employment. A total of 55 possible risk factors were statistically analyzed with a single factor analysis. On the basis of the single analysis, nine factors including drinking, smoking, and education were further analyzed with a conditional logistic regression model.

*b.* A calculation was made on the odds ratio of each factor selected into the model. According to the estimated parameter of the established logistic model, the relative risk of the risk factors could be worked out. Finally, two factors, the amount of ethanol drunk on each occasion and the frequency of drinking every week, were selected into the model at the level of  $\alpha = 0.05$ . The result showed that these two factors have a dose-response relationship with their odds ratio of occupational TNT liver damage, but there is no connection between smoking and occupational TNT liver damage and no interaction between drinking and smoking.

c. The above results have revealed that people exposed to TNT and with a long history of heavy drinking, have a greater risk of suffering from chronic liver impairment than those that do not drink.

Morton AR, M.V. Ranadive, J.A. Hathaway. 1976. Biological effects of trinitrotoluene from exposure below the threshold limit value. *Am Ind Hyg Assoc J*, Jan;37(1):56-60.

(ABSTRACT—)

a. Statistically significant rises in serum glutamic oxalacetic transaminase and lactic dehydrogenase determinations occurred at exposures to TNT of 0.8 mg/m<sup>3</sup> and persisted at exposures of 0.6 mg/m<sup>3</sup>.

b. Based on these findings, the adequacy of the current threshold limit value for TNT (1.5 mg/m<sup>3</sup>) is questioned.



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## Glossary

### Abbreviations

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**ACGIH**

American Conference of Governmental Industrial Hygienist

**ALP**

alkaline phosphatase

**ALT**

alanine transaminase

**ANSI**

American National Standards Institute

**AR**

Army Regulation

**AST**

aspartate transaminase

**CBC**

complete blood count

**CFR**

Code of Federal Regulations

**COCO**

Contract-Owned, Contract-Operated

**cyb5**

cytochrome b5

**DA**

Department of the Army

**DA Pam**

Department of the Army Pamphlet

**DD**

Department of Defense

**DNAT**

dinitroaminontoluene

**DoD**

Department of Defense

**EMF**

employee medical folder

**F344**

Fisher 344

**g**

gram

**g/dL**

grams per deciliter

**G6PD**

Glucose-6-phosphate dehydrogenase

**GGT**

gamma glutamyl transpeptidase

**GOCO**

Government-Owned, Contractor-Operated

**H&H**

hemoglobin and hematocrit

**HIPAA**

Health Insurance Portability and Accountability Act

**HPF**

high-power field

**IARC**

International Agency for Research on Cancer

**IH**

industrial hygiene

**IRIS**

Integrated Risk Information System

**LEV**

local exhaust ventilation

**MEDCEN**

Medical Center

**mg/m<sup>3</sup>**

milligrams per cubic meter

**mmol/dL**

millimol per deciliter

**NaOH**

sodium hydroxide

**NIOSH**

National Institute for Occupational Safety and Health

**OH**

occupational health

**OHP**

occupational health physician

**OSHA**

Occupational Safety and Health Administration

**PEL**

permissible exposure limits

**PPE**

personal protective equipment

**RC**

reticulocyte count

**SF**

Standard Form

**SOP**

standing operating procedure

**TLV**

threshold limit value

**TNT**

2, 4, 6-Trinitrotoluene

**TWA**

time-weighted average

**UA w/micro**

urinalysis with microscopic

**USAMC**

U.S. Army Material Command

**USAPHC (Prov)**

U.S. Army Public Health Command (Provisional)

**USEPA**

U.S. Environmental Protection Agency

**USAJMC**

U.S. Army Joint Munitions Command

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